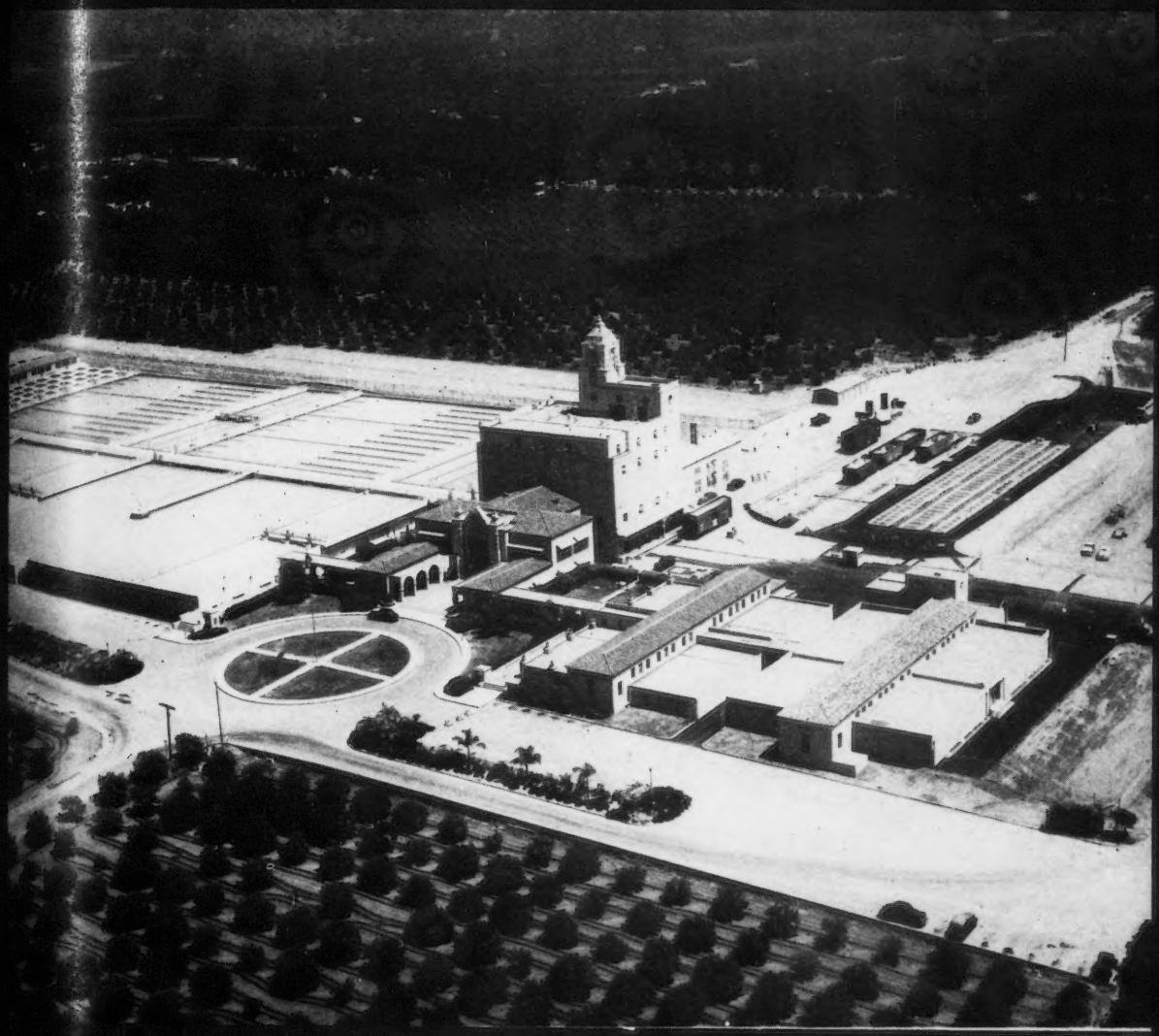
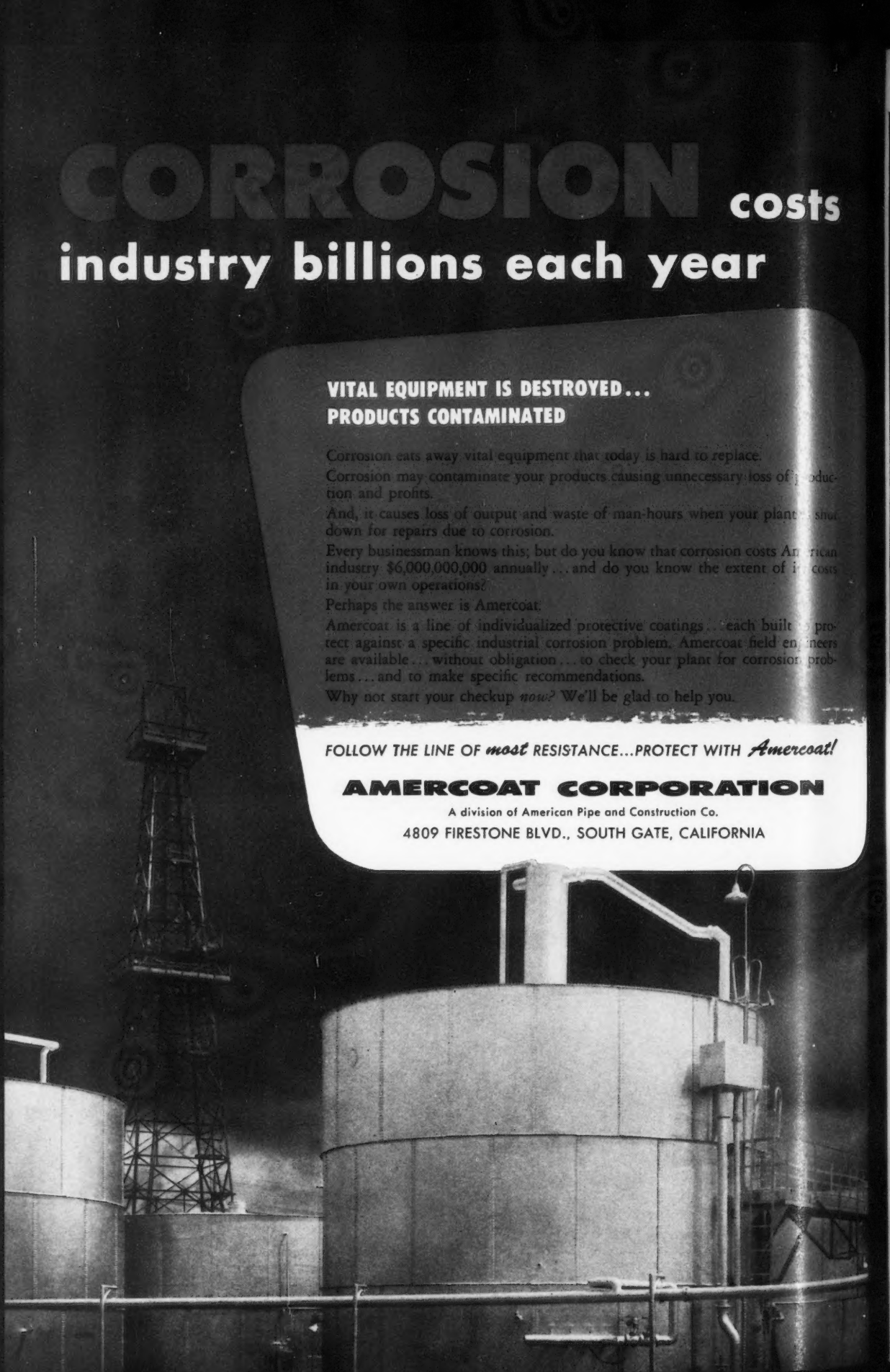
# Corrosion

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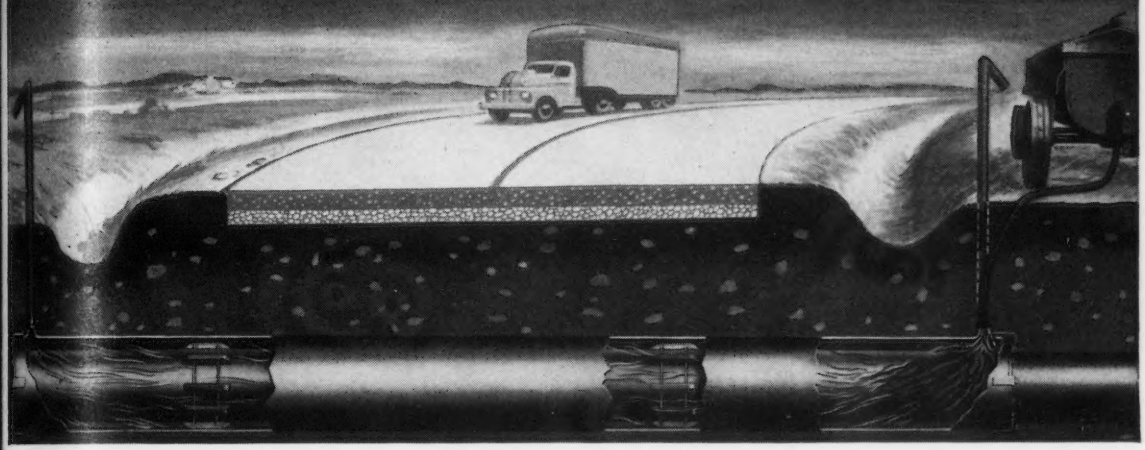

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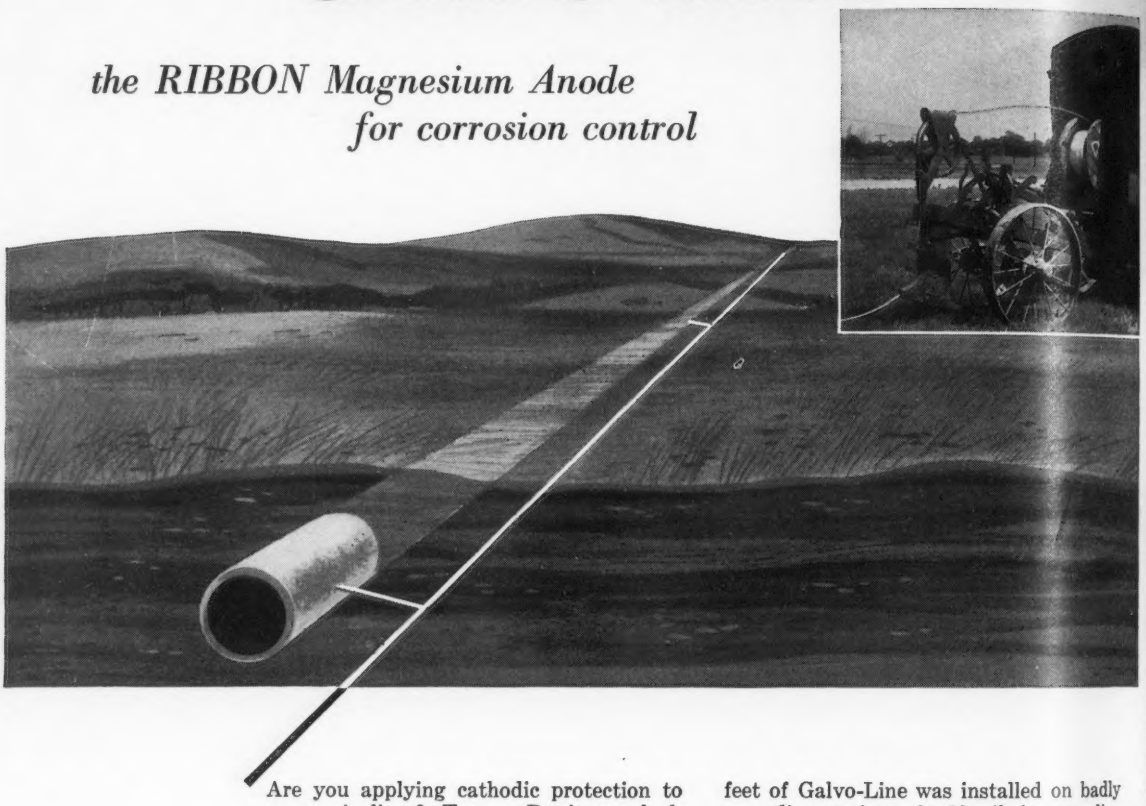

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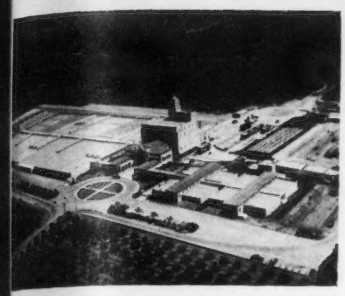

THIS MONTH'S COVER—This is the F. E. Weymouth Memorial Softening and Filtration Plant of the Metropolitan Water District of Southern California at Laverne. Initial clarifier and flocculator basins are at left foreground while basins added later are directly behind. Filter buildings are at extreme left. Administration building and headhouse are in center and zeolite softener buildings are at lower right. Citrus groves surround the plant. (Photo by Pacific Air Industries.)

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*devoted entirely to* **CORROSION** *research and control*

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VOL. 8 — APRIL, 1952 — NO. 4


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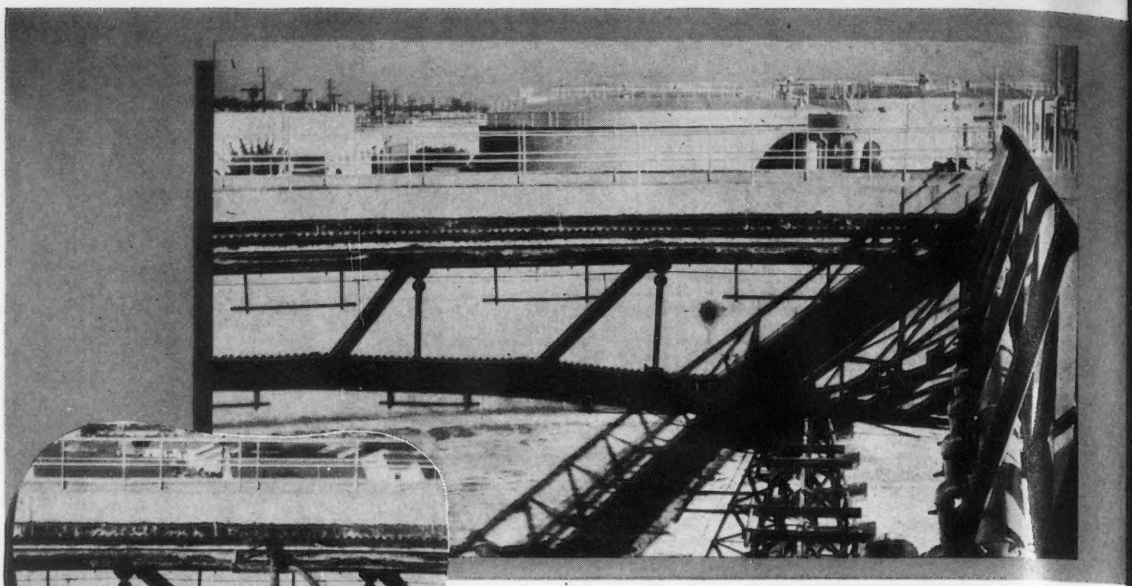

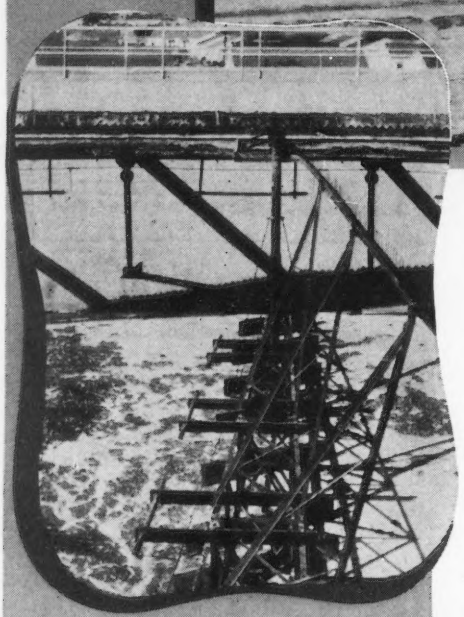

# HANDLING WASTE ECONOMICALLY

## . . . another *BIG* job for

# NATIONAL
TRADE-MARK

## GRAPHITE GROUND ANODES

Modern sewage-disposal systems are a boon to public hygiene – but they can be mighty hard on *submerged metal structures.*

The San Diego Municipal Sewage Plant employs a number of settling tanks like the one illustrated above. Formerly, their massive steel agitators were ravaged by galvanic corrosion . . . underwent extensive and costly repairs at intervals averaging 5 years.

Then cathodic protection, using "National" Graphite Ground Anodes, was applied. Now, after more than 2½ years of service, neither the steel nor the 80 Graphite Anodes shows any sign of deterioration.

In this instance, municipal management found the cost of cathodic protection handsomely justified by maintenance and material economies. Equipment – and the taxpayers' dollar – have a new, long-term, trouble-free lease on life.

**CATHODIC PROTECTION SAVES STEEL**

*The term "National" is a registered trade-mark of Union Carbide and Carbon Corporation*

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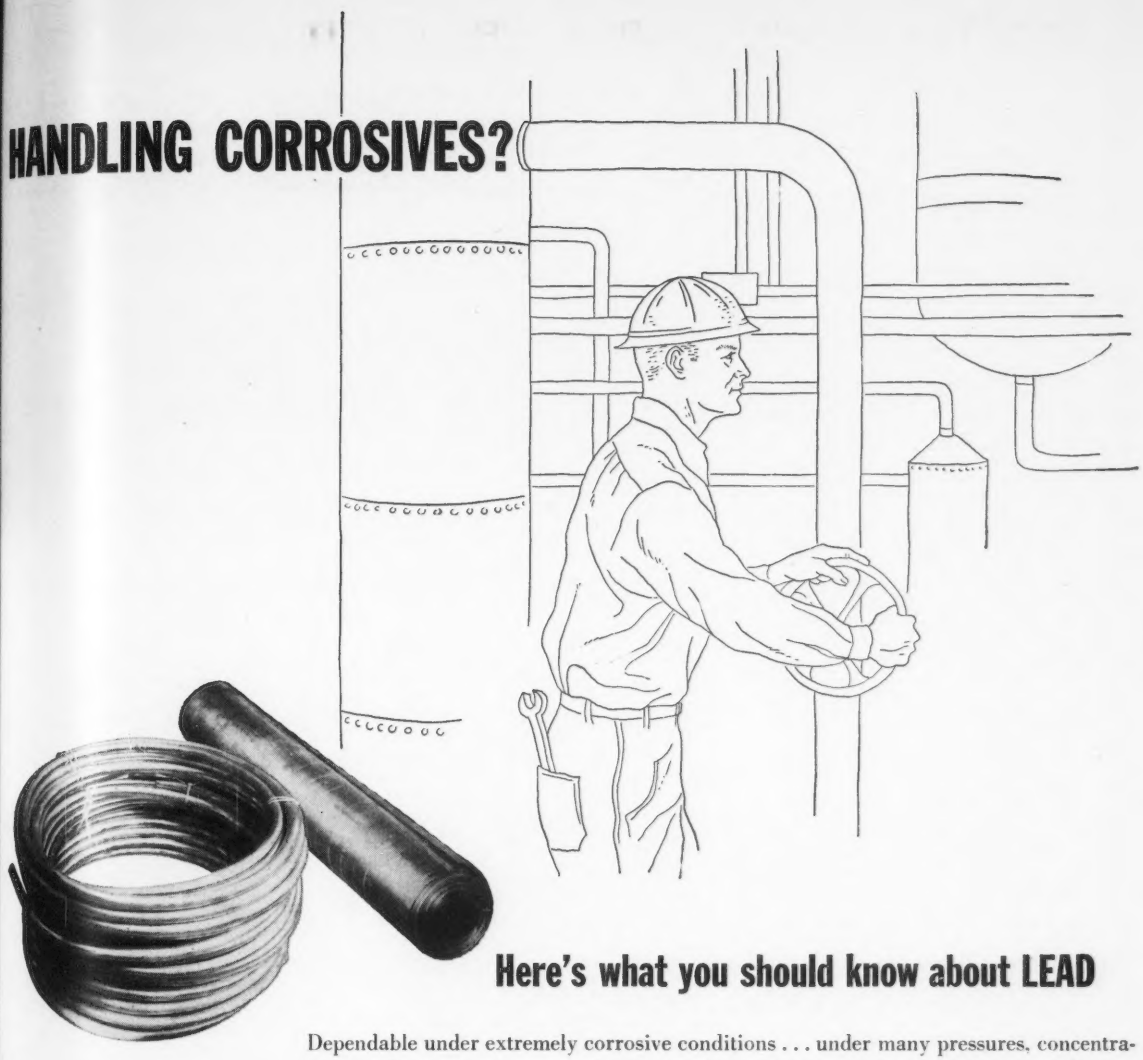
# HANDLING CORROSIVES?



## Here's what you should know about LEAD

Dependable under extremely corrosive conditions . . . under many pressures, concentrations and temperatures . . . lead is the ideal material for handling sulphuric, sulphurous and chromic acids. In the chemical, textile, petroleum and metallurgical industries . . . wherever reliable control of strongly corrosive harsh-acting materials is imperative, lead can be used safely.

Lead can be fabricated to meet special conditions. Sheet lead can be welded, or "burned", to form a continuous lining; it can be bonded to another metal. Lead can be cast, die cast or pressure molded; extruded as pipe or other shapes; fastened by welding, flanging or bolting. Once installed, lead chemical equipment is easily repaired with a welding torch and requires no annealing or subsequent heat treatments.

For complete technical assistance with your corrosive-handling problem, write to Federated's *Corrosion Advisory Service*. It is at your service.

For lead products, use ASARCO Brand lead pipe, lead sheet, and lead fittings. Available in all standard sizes and forms through Federated's 22 sales offices across the country.

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# SIMPLE TEST

## may save you millions

(1) Control (2) 3 ppm Santolene C (3) 7½ ppm Santolene C

You don't need a laboratory to make this simple test to prove that Monsanto Santolene C can solve your corrosion problems. It may point the way to saving millions lost through corrosion damage to tanks, tankers, pipelines and refinery equipment.

Fill three bottles with 75 grams gasoline, kerosene or other light petroleum product. Add 2 cc water to each bottle. Use one as the control. Add 3 ppm and 7½ ppm of Santolene C to the other bottles. Drop a strip of clean steel into each of the bottles. Notice how soon corrosion starts on the metal in the uninhibited gasoline and how bright the other test strips remain.

This test demonstrates the effectiveness of Santolene C in the control of corrosion under static conditions. Tests of corrosion control with Santolene C under dynamic conditions have been equally spectacular.

Minute quantities of Santolene C, added to gasoline, kerosene and other light petroleum products, effectively control corrosion. This has been proved in actual use by major oil refiners.

If you would like to test Santolene C as suggested here, we'll be glad to send you a sample of the product. MONSANTO CHEMICAL COMPANY, Organic Chemicals Division, 1700 South Second St., St. Louis 4, Missouri.

# SANTOLENE C

*Santolene: Reg. U.S. Pat. Off.*

MONSANTO
CHEMICALS AND PLASTICS

SERVING INDUSTRY... WHICH SERVES MANKIND

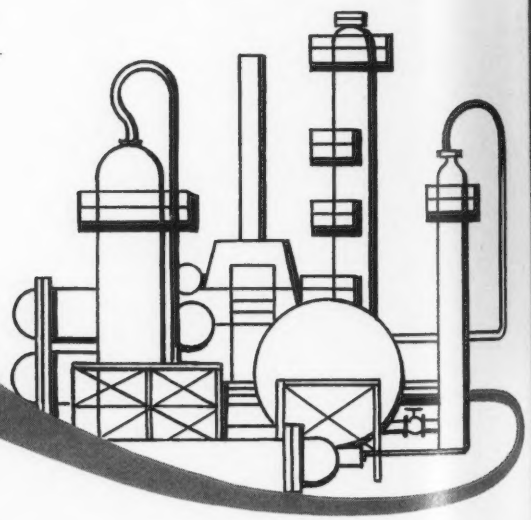
# FOR BETTER PROTECTION AGAINST CORROSION IN THE REFINERY

Kontol is a non-volatile, heat-stable, semi-polar organic corrosion preventive. It is soluble in most distillates and crude oils and is available in two forms, water-insoluble and water-emulsifiable. It protects against corrosive attack by adsorbing at metal surfaces in the form of a thin, impervious film, thereby preventing contact between corrosive elements and metals. Excellent protection has been attained when temperatures were as high as 300°F. Kontol is stable at temperatures up to 550° F plus.

Kontol has been effective in preventing corrosion in piping systems, pumps, fractionating towers, stripping columns, cooling water systems, heat exchangers and separators. Injected into a refinery system, Kontol continues to afford corrosion protection to all the metal surfaces it contacts, consequently, its protection action is extended downstream from the initial injection point.

The use of Kontol does not affect the properties of refined products, such as end point, gum formation, anti-knock rating, color, ash, etc.

*If corrosion is causing lost on-stream time in your refinery, request a Tretolite Company corrosion rate survey. Such a corrosion survey is yours for the asking and entails no obligation. It may enable your refinery to substantially reduce corrosion losses. Why not request it today?*

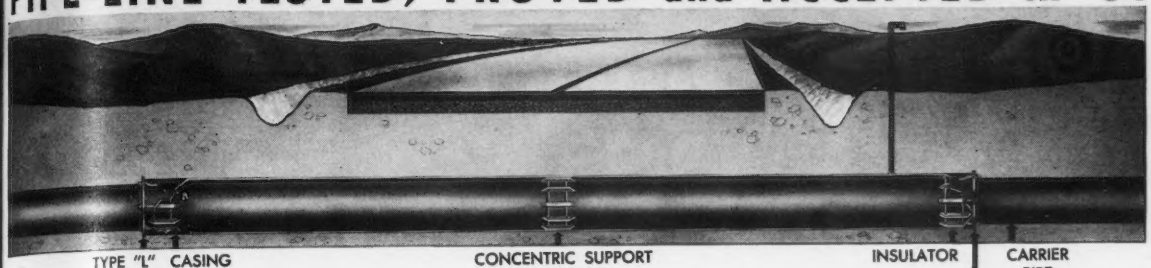


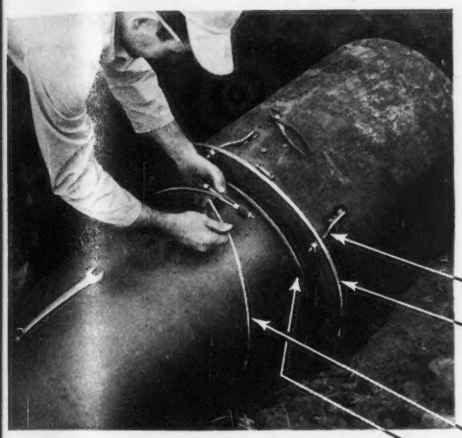
**TRETOLITE COMPANY**
SAINT LOUIS 19, MISSOURI
LOS ANGELES 22, CALIFORNIA

***CHEMICALS FOR THE PETROLEUM INDUSTRY***
**CORROSION INHIBITING • DESALTING**
**DEHYDRATING • WATER DE-OILING**
**SCALE PREVENTING**

KB 52-4

# PIPE-LINE TESTED, PROVED and ACCEPTED in '51

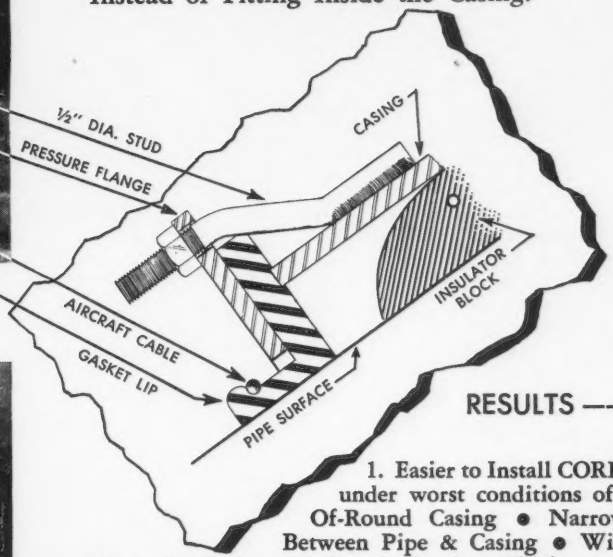


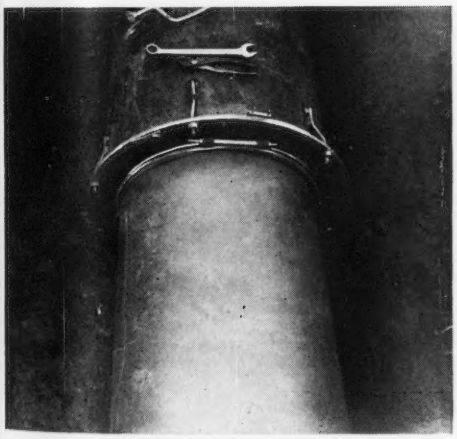



Assembling cable with rubber-covered union for clamping gasket lip to pipe.

## TYPE "L" WmSEAL CASING BUSHING*

**A New Design· It BUTTS Against End of Casing Instead of Fitting Inside the Casing.**



THE COMPLETED INSTALLATION
Note that galvanized cable and union are insulated from pressure flange and from pipe.

**RESULTS ——**

1. Easier to Install CORRECTLY under worst conditions of • Out-Of-Round Casing • Narrow Space Between Pipe & Casing • Wide Variations in Casing Wall and Coating Thickness • Mud • Casing ends beveled — by machine or hand torch.
2. WATER-TIGHT Seal with "L" gasket . . . . . .
   - BUTTED AGAINST CASING as pressure flange is tightened on ½" studs welded to casing.
   - TIGHT TO THE PIPE as aircraft cable (4,600# tensile) is tightened to gasket lip. Union is rubber covered to INSULATE galvanized cable assembly from bare casing structure.
3. Always Insulated from the pipe line when a Concentric-Support Insulator is installed just inside casing after the "drag section" is in place.

**AS STRONG & DEPENDABLE AS THE MEN WHO INSTALL THEM**

**REPRESENTATIVES**

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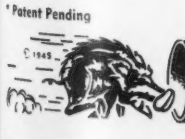
* Patent Pending

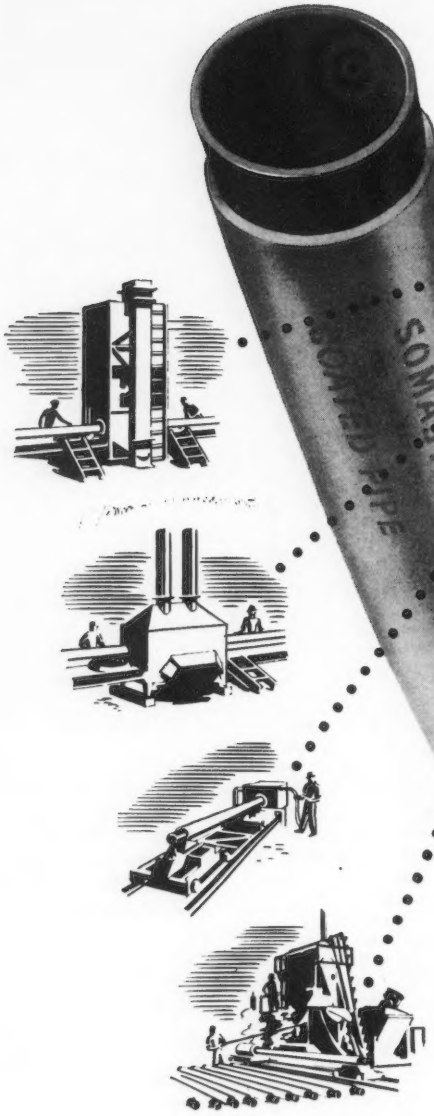
**WRITE FOR COMPLETE INFORMATION**




THE PIG WITH THE POKE CLEANS PIPE LINES

**T. D. Williamson, Inc.**
TULSA 9, OKLAHOMA

# SOMASTIC* PERMANENCE
## includes TIME TESTED METHODS of Application




For the past 20 years SOMASTIC PIPE COATING has been applied to pipe by standard practices which only now are being adopted generally by the pipe coating industry. Time has proved them most effective. These methods are—

★ *Thorough cleaning of metal by grit-blasting.*

★ *Pre-heating, followed by hot priming, assuring a firm, lasting bond of coating to steel.*

★ *Selection of materials and manufacture of coating to rigid specifications.*

In addition, SOMASTIC leads in this essential feature—

★ *Application of coating to primed pipe in a continuous process by special* SOMASTIC *equipment to form a dense, compact, uniform and seamless protective coating of great durability.*

The general swing to methods pioneered by SOMASTIC Pipe Coating is another acknowledgment of a fact first shown by the API-Bureau Of Standards Ten Year Pipe Coating Tests . . . and since proved at thousands of corrosive locations . . . for *permanence* coat with SOMASTIC.

**SOMASTIC**
*Reg. U. S. Patent Office
**PIPE COATING**

***Unequaled for PERMANENT PROTECTION***
**SOMASTIC IS The Best PIPE COATING**

MANUFACTURED BY

**H. C. PRICE CO.**
BARTLESVILLE, OKLAHOMA
PHILADELPHIA, PA. • NEW ORLEANS, LA.
In the 37 States East of the Rocky Mountains

**BECHTEL CORPORATION**
SAN FRANCISCO and WILMINGTON
CALIFORNIA
In the 11 Western States and in Foreign Countries

# TYGON

## *Versus* $CH_3COOH$

COMBATTING the attack of acetic acid has long been a problem to plant designers, process engineers, and maintenance men. Virtually all of the usual corrosion-resistant materials have been tried, but few have proved completely successful. Even the family of TYGON plastic compounds with its unusual versatility and chemical resistance is not the complete answer. However, with proper use, TYGON can, and does, give economical, enduring protection against acetic acid in many instances.

Essentially, TYGON consists of polyvinyl resins carefully modified with other materials to give the optimum in chemical and physical properties. However, because of its organic nature the resistance of TYGON to acetic acid varies according to the specific compound and physical form used and the conditions of exposure. In some cases, TYGON has failed. In many more cases, TYGON has done a job no other material could do. The key to success of TYGON against acetic acid lies in the use of the right compound and the right physical form. The key to use of the right compound and form lies in consultation with U. S. Stoneware engineers.

For instance, as a press-polished sheet TYGON is used to line or cover tanks, drums, hoppers, bins, blowers, impellers, fume hoods and fume ducts. In such uses, TYGON resists acetic acid, in concentrations up to 15% by weight, at temperatures as high as 165-175°F. With concentrations greater than 15%, the temperature limit drops to 150°F. However, these limits may change according to the conditions of a specific application. Particularly does the use of acetic acid with its anhydride, other acids, or certain solvents make a difference. In addition, the TYGON compounds used in lining work usually are not recommended, because of toxicity, for use with foods. Thus, it is wise to consult a qualified engineer.

With TYGON sheets that are die-cut and used as gaskets, advice on chemical resistance is less essential. Because of the small exposed area of a gasket, TYGON can be used with acetic acid in any concentration and at temperatures up to 200°F. However, certain conditions such as high pressures or use with foods warrant consultation. A molded gasket reinforced with glass fibers may be needed to handle the pressure, while a gasket of a non-toxic TYGON compound must be used for food.

When using molded TYGON as gaskets, grommets, washers, stoppers, handles, bumpers, or special fittings, concentration of the acid is not a factor and temperature limits again range as high as 200°F. Advice is suggested, however, on design of the piece, on questions of toxicity, and on use with other chemicals.

In extruded form, TYGON is used primarily as tubing or piping although extruded solid cord, channel and tape are also used as gasketing and coverings. As an extrusion, TYGON resists acetic acid in any concentration and at temperatures up to 200°F. Where tubing is used as flexible connections, as transfer lines, as ports on acid pumps, or as syphon hoses, engineering advice usually is not necessary because of the number of standard formulations and sizes (up to 2" ID) available. However, in work with constant pressures of more than 40 psi or mixtures with other chemicals, braided jacket reinforcement or other precautions may be needed and consultation is suggested.

As a paint, TYGON is used to protect all types of equipment, structural steel, walls and ceilings against the fumes and spillage of acetic acid, but only under mild conditions. The physical limits of a thin film prevent the recommendation of TYGON Paint against fumes and spillage of high concentration and at elevated temperatures. In all uses with acetic acid previous tests are suggested.

As a plastisol (TYGOFLEX), TYGON finds use as a heavy duty coating and in the casting or "slush" molding of flexible parts and fittings. As such, its resistance to acetic acid varies according to the thickness of the TYGOFLEX involved, but usually is comparable to that of gasketing.

Although its use against acetic acid is approached rather conservatively, as compared to its use with other chemicals, TYGON can provide long lasting and low cost protection. Its flexibility, toughness, abrasion resistance, and in some cases, clarity, permit its economical and advantageous use in many applications.

TYGON plastics

*In addition to TYGON in its various forms, we also manufacture a number of other materials capable of handling acetic acid in any concentration and under all types of operating conditions. These products include chemical stoneware and porcelain, acid proof brick and cements, homogenous lead linings, and other organic linings and coatings.*

*Why don't you submit your corrosion problem today? There's no obligation and we'll be pleased to be of assistance. So write, now!* 324-c

**THE UNITED STATES STONEWARE CO., Akron 9, Ohio**

ENGINEERS, MANUFACTURERS, ERECTORS OF CORROSION-RESISTANT EQUIPMENT SINCE 1865

# THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.

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Corrosion

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An Association of Individuals and Organizations Concerned with Control of Corrosion

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# Regional Management Committee

By L. A. BALDWIN, *Chairman*

*Johns-Manville Sales Corp., New York, N. Y.*

AS COVERED in the original National Association of Corrosion Engineers' by-laws, the Regional Management Committee consisted of at least five members and a chairman, all appointed by the Board of Directors of the Association. The function of this committee was to help in the organization of Regional Divisions and to prepare and assist in the execution of policies, activities and plans as well as coordinate the work of such Divisions.

The first committe, under the chairmanship of Mr. George McComb, ably performed this service and was useful in formulating model by-laws for the guidance of Regions and the supplying of valuable advice and counsel. It was recognized that the Regions were all important in developing Sections from which NACE could anticipate the future growth of the organization.

With completion of the Regional organizations this phase of the Committee's activities became less important. At the same time the growth of local Sections, (we now have twenty-six), presented more problems to the officers of the Region and the Regional Management Committee.

In 1949, with the approval of Dr. R. B. Mears, President, your chairman suggested the membership of the Committee should consist of all Regional and Sectional officers and that meetings be held in connection with each annual conference. Three such committee meetings have been held and all Regional and Sectional officers have been encouraged to bring up their problems. Attendance at these meetings has run as high as forty or fifty and, while it has not always been possible to satisfy every member, we have been able to clear up many misunderstandings and work out many procedures for action by the Board of Directors. Most of this has applied to the Sections.

Each year these meetings have represented a cross section of Regional and Sectional management thus providing a sounding board for the management and have also been attended by the President and Vice President who have been able to get at first hand the opinions of individual members through local management.

This Committee organization has been approved in our new articles of Organization, effective January 1, 1950.

# Performance of Magnesium Galvanic Anodes In Underground Service*

By OLIVER OSBORN and H. A. ROBINSON

## Introduction

DEMONSTRATING the suitability of magnesium or any other metal for use as a glavanic anode is decidedly a more complex affair than simply citing its position in the electromotive series. A favorable position in the series is only a tentative endorsement. The polarity of a metal relative to others may be subject to reversal with changes in the electrolytic environment or poor polarization characteristics may nullify an otherwise acceptable electrode potential. At best, it is only the first and most elementary consideration in a gantlet of criteria which the metal must pass to properly qualify for the application.

If the candidate metal qualifies in the above respects, there remains the task of checking on other electrochemical properties, notably its electrochemical equivalent, anode (current) efficiency and corrosion pattern. The electrochemical equivalent provides a measure of the quantity of electricity (ampere-hours) contained in a unit weight of the metal. Anode efficiency indicates how much of the stored electricity is recoverable as useful current under service conditions. The distribution of the corrosion attack gives some indication of how completely a given mass of the metal can be utilized in practice. Obviously, all of the above are important indices of anode performance.

Short term laboratory or field tests may demonstrate that the metal has adequate qualifications in all of the foregoing categories and yet leave the corrosion engineer in need of vital information. That information is essentially concerned with the effect of time—long periods of time—on anode performance. Most underground galvanic anode installations are designed for a service life of from five to fifteen years, ten year life being a rather common design basis. Except for a few two year tests, the laboratory and field tests reported heretofore have covered periods of time ranging from one to twelve months for the most part. Attempting to predict anode performance over periods of five to ten years or more on the basis of these short term data would obviously be unwise.

Complicating the problem on underground installation is the conventional practice of using a specially formulated chemical mixture or backfill to modify and stabilize the anode environment. The combination constitutes what might be termed a half-cell. Many different backfill formulations are possible and it is recognized that anode performance can be modified to some extent by the choice of backfill formulation. It is also reasonable to expect that backfills in service will be subject to chemical and physical changes with aging owing to the action of ground waters, atmospheric gases and other agents in the soil. Thus different backfill formulations are likely to exhibit varying degrees of chemical and physical stability with the passage of time and this in turn may modify anode perofrmance with respect to time. Accordingly, the problem becomes one of studying not only the effect of backfill composition on anode performance, but also the effect of time, and the climatic variables introduced by the passage of time, on the performance of various anode-backfill combinations or half cells.

**OLIVER OSBORN** is a native Texan and a graduate of Texas A. & M. with a BS in chemical engineering. For the past ten years he has been with Dow Chemical Company. Presently he is in charge of the Electrochemical Engineering Department of the Dow Texas Division. Mr. Osborn has been active in an extensive program for development of uses of magnesium for cathodic protection. He is currently trustee of Houston Section, NACE.

**H. A. ROBINSON**, Assistant Director Laboratory Development, Metallurgical Laboratories, The Dow Chemical Company, Midland, Mich., is a native of Pennsylvania, and holds a BS degree in chemical engineering from Case Institute of Technology 1931. Since 1931 he has been engaged continuously in research and development work with Dow Chemical Company, principally with potentiometric measurements and analysis and with corrosion studies, notably with magnesium anodes used for cathodic protection. His current interests include corrosion and electrochemical or chemical uses of magnesium.

## Scope of Testing Program and Test Procedures

Recognizing the need for the long-range data noted above, The Dow Chemical Company has continued to study the performance of magnesium anodes in underground service. In contrast with earlier work which dealt largely with the effects of anode composition, the work covered by this paper is concerned principally with the effects of time and backfill formulations on anode performance. The

★ A paper presented at the Sixth Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., April 4-7, 1950.

## Abstract

The performance of magnesium galvanic anodes in underground service is reviewed in the light of the past five years of field testing in which upwards of 2500 anodes have been tested in some 40 different backfills and in various soils. The pertinent indices of galvanic anode performance are cited and the various factors influencing the performance of magnesium anodes are enumerated. A summary of the most outstanding findings relative to anode current efficiency, anode current output and stability of current flow is presented. The effects of such factors as anode composition and impurities, current density, time, backfill composition, installation practice, soil characteristics, and weather on anode performance are discussed. The high purity Mg-6Al-3Zn alloy continues to provide the most consistently efficient performance. At current flows equivalent to ten year life, efficiencies corresponding to 500 ampere-hours per pound are usually realized except in high chloride soils where higher current densities are needed to get comparable efficiencies. Impurities, notably nickel, iron, and copper must be held at low concentration levels in order to realize good anode efficiency. Pure commercial (cell) magnesium anodes occasionally exhibit high efficiencies but statistical experience shows their performance to be decidedly inferior to that of the high purity alloy. Field tests show the efficiency of the alloy anodes to increase with current density as previously indicated by laboratory data. Likewise, efficiency tends to increase with time for periods up to at least two years. With the exception of the magnesium sulfite and chromic acid backfills, the composition of the backfills used appears to have no very significant effect on anode efficiency.

Anode current output is essentially a function of soil resistivity and cathode potential although it is influenced to some extent by backfill composition and backfill installation practice. Statistical data indicates that backfills installed dry provide a higher level of current output than is obtained with wet (mud) backfills. Likewise, high conductivity backfills appear to provide significantly higher current flow.

Excellent maintenance of current flow has been observed for periods of three to five years on relatively large numbers of anodes. The most stable current flows are associated with deep installations and poor to fair soil drainage. Well drained installations on slopes or elevations tend to exhibit poor current maintenance. Depletion of soluble backfill ingredients (gypsum, sodium sulfate) is evident after three to four years of service but current flow is not adversely affected so long as the moisture supply is adequate. Bentonite rich backfills are highly moisture sensitive and tend to expand or shrink excessively with fluctuating moisture levels. If installed wet they sometime shrink enough to adversely affect anode-to-earth resistance. Stability of current flow is also affected by rainfall and temperature, the temperature effect being most pronounced where winters are coldest. Current flows are usually well maintained until the anode is 85-95 percent exhausted.


influence of incidental or uncontrollable variables such as anode current density, soil characteristics, rainfall and temperature was also observed insofar as was practical.

The test work has been carried out at both Midland, Michigan, and Freeport, Texas, and this paper will attempt to present experience data from both places. At the Freeport site, tests were made in soils of both low (50-100 ohm/cc) and intermediate (500-1000 ohm/cc) resistivity. The low resistivity soil here is highly saline (See Table I) due to contamination by sea water and its general occurrence is probably limited to coastal marshes. The soil of intermediate resistivity seems likely to be fairly typical of the Gulf Coast area in general. Soils at the Midland site range in resistivity from 1000 to 10,000 ohms/cc, except for occasional pockets of low

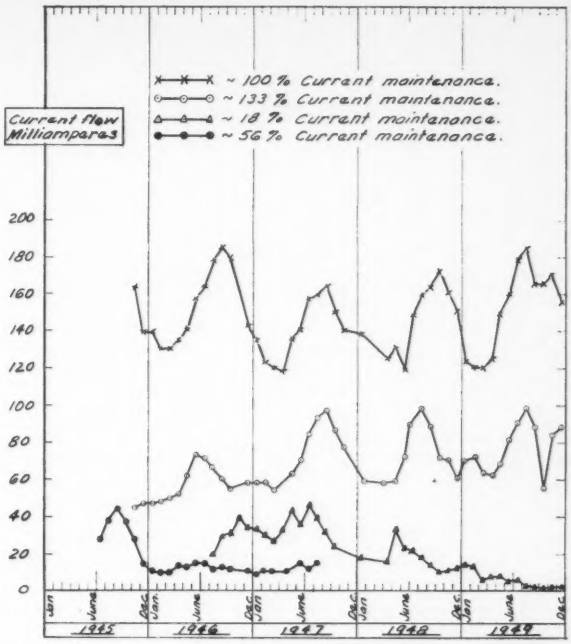



**Figure 1—Current-time logs of four 17-lb. field anodes illustrating various degrees of current stability.**

resistivity soil resulting from brine seepage. Both extremely sandy, well drained soils and tight, poorly drained clay soils were encountered in making test installations at the latter site.

Most of the test data are derived from actual underground installations on operating pipe lines although some data are taken from laboratory drum tests[1] which simulate field conditions but have the advantage of permitting precise control of anode current density. The test installations at Freeport were made on both bare and coated structures whereas those at Midland were all coupled to bare pipe cathodes. In evaluating current maintenance no correction has been made for cathode polarization, since polarization took place quite rapidly and varied in a fairly reproducible manner from year to year. Accordingly, the current maintenance data presented are, if anything, conservative.

In all, some three thousand anodes have been placed on test and about forty different backfill compositions have been investigated. Not all of these have been long term tests since some of the backfill formulations could be eliminated on the basis of short time tests alone. The data reported here are

**TABLE I**

**Soil Analyses—Freeport, Texas**

| CONSTITUENT | SOIL DESCRIPTION | |
|---|---|---|
| | 100 Ohm/cc | 500-1000 Ohm/cc |
| Percent $HCO_3$ | 0.16 | 0.1 |
| Percent $CO_2$ | 4.6 | 3.1 |
| Percent $N_2$ | 0.08 | 0.00025 |
| Percent Acid Soluble Fe | 1.9 | 2.2 |
| Percent Acid Soluble CaO | 6.1 | 4.6 |
| Percent Acid Soluble $SO_4$ | 0.16 | <0.06 |
| Percent NaCl | 0.68 | 0.0103 |
| Percent Inerts | 86.4 | 89.9 |
| pH | 8.7 | 7.9 |

for test periods ranging from six months to four years and in some instances the tests are scheduled to continue for several years longer.

Current flows were measured by means of a shunt resistance (0.1 or 0.01 ohms) inserted in each anode lead wire. Measurements were made at weekly or monthly intervals depending upon the duration of the test. In soils of low resistivity, current flows were restricted to the desired levels by the use of suitable resistance in the anode lead wire. Anodes were removed after fixed periods of operation, cleaned and weighed. Their efficiencies were then computed from the observed weight losses and the integrated weekly or monthly current readings.

Various methods of installing backfill were practiced in making the test installations. In some cases the backfill was introduced into the hole as a wet mud; in others it was placed around the anode as a dry powder. A third practice was to place both anode and backfill (either wet or dry) in a suitable sack and introduce the packaged unit into the hole.

To simplify description of the various backfills tested, code letters were assigned to some of the common backfill components. A listing of these components and the corresponding code letters is given below:

| | |
|---|---|
| B = bentonite | G = gypsum (hydrated) |
| PP = Plaster Paris | Na = sodium sulfate |
| M = magnesium hydroxide | MI = magnesium sulfite |
| R = chromic acid | Ce = Celite |

Thus, 3B1G describes a backfill containing three parts (volume) of bentonite and one part (volume) of gypsum. This code will be used throughout the paper.

The choice of anode compositions for this work was restricted essentially to pure commercial (cell) magnesium and the high purity Mg-6%Al-3%Zn alloy (primary grade), although a small amount of secondary Mg-6%Al-3%Zn alloy was also tested. For the most part, the tests were made using either the 16 lb., 4 inch x 20 inch round anode or the 17 lb., 4 inch x 20 inch D-section anode.

*Practical Criteria of Anode Performance*

In evaluating the data from the above tests the major emphasis has been placed on those aspects of anode performance which are of the greatest practical interest to the corrosion engineer. These include:

1. Anode efficiency, i.e., ampere-hours delivered per pound of metal consumed, since this has a direct bearing on the cost of the current supplied by the anode.
2. Current output per anode as affected by backfill formulation, soil resistivity and backfill installation practice, inasmuch as this factor affects both installation design and the cost of installation per ampere of current supplied.
3. The maintenance of current flow over long periods of time. The question posed here is whether or not the current flows realized initially will be reasonably well maintained over an extended period of time in view of such factors as polarization, accumulation of corrosion products, backfill depletion and a progressive reduction in anode volume. Experience in this case would have a bearing on installation design and might even affect the decision to use the anode at all. For the purposes of this paper the stability of the anode current flow over an extended period of time will be expressed as % current maintenance. This is defined as the ratio (x 100) of the ampere-hours delivered by the anode during the most recent year of service to the ampere-hours supplied during the first year of service. This method of indicating stability is a rough but fairly serviceable one as is indicated by Figure 1, where % current maintenance values have been assigned to the current-time logs of anodes exhibiting varying degrees of current stability. It does not, of course, distinguish as to the causes of the variations in current maintenance and in this respect may be misleading, e.g., deviations of as much as ± 25 percent or more from 100 percent current maintenance may be due to nothing more than large variation in yearly rainfall. Ordinarily, however, a substantial deviation from 100 percent maintenance indicates a definite, long term trend.

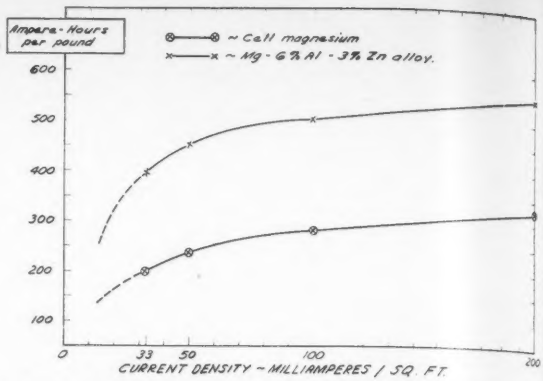



**Figure 2—Relative performances of cell magnesium and Mg-6%Al-3% Zn anodes in highly saline soils. Data taken from field test at Freeport, Texas, sea water flume comprising 192 anodes and 8 backfills. Test duration one year. Soil resistivity equals 100 ohms/cc. Anode current flow regulated with resistors.**

*Factors Affecting Anode Performance*

Previous work and the work to be described here have shown that overall anode performance is influenced by several different factors, the most outstanding of which are listed below:

1. Anode composition and impurities.
2. Anode current density.
3. Time.
4. Backfill composition.
5. Backfill preparation and installation practice.
6. Soil composition and characteristics.
7. Rainfall and soil temperature.

Accordingly, the various data from the experimental program described above will be reported largely in terms of the effect of these variables on anode performance.

## Effect of Anode Composition and Impurities

Although pure commercial or "cell" magnesium has the advantage of a potential about 0.1 volt more anodic than the Mg-Al and Mg-Al-Zn alloys, the field results at both Freeport and Midland show it to be a decidedly less efficient anode material than the high purity Mg-6%Al-3%Zn alloy. This observation is supported by the comparisons shown in Figures 2, 13, and 14, and by the data presented in Tables II, III, and IV. In general, these data demonstrate that cell magnesium cannot be depended upon to produce more than about 50 to 60 percent of the ampere-hour output afforded by the alloy anodes, although there have been instances of individual cell magnesium anodes functioning as efficiently as the alloy anodes.

Considerable effort has been expended in attempting to improve the efficiency of cell magnesium and thereby take advantage of its higher potential. Practical means for precipitating the iron from cell magnesium have been developed such that magnesium containing as little as 0.001-0.003 percent iron can readily be produced. This partially purified material exhibits an improved anode efficiency but removal of iron alone does not suffice to give the efficiencies attainable with the high purity Mg-Al-Zn alloys. This is particularly true in low resistance media. Apparently other impurities in addition to iron must also be controlled to achieve this result.

At present, cell magnesium can be expected to perform efficiently only under special circumstances, as for example, under conditions where current densities in excess of about 500 ma/sq. ft. can be realized. The "low iron" magnesium, prepared by the precipitation methods described above, will function efficiently in waters and soils having a resistivity of 3000-5000 ohms/cc and above. A comparison of its performance with that of ordinary cell magnesium is shown in Figure 3. Material of this type is used in the cored ribbon anode (Galvo-Line).

No very extensive investigation of the effect of impurities on the performance of the Mg-6%Al-3%Zn alloy has been made in the field, largely because such studies can be made more rapidly and thoroughly in the laboratory with results which correlate well with field experience. In the early field work on magnesium anodes the injurious effect of high nickel concentrations was observed and reported.[1] In more recent field tests the performance of the high purity Mg-6%Al-3%Zn alloy has been compared with that of the same alloy inadvertently contaminated with lead and iron, and with secondary

**TABLE II**

**Performance of 17-Lb. Cell Magnesium Anodes at Freeport Test Site***

| (Soil Resistivity) | 50 to 100 Ohm/cc Soil | | | | | | | | 500 to 1000 Ohm/cc Soil |
|---|---|---|---|---|---|---|---|---|---|
| | Six Months Ampere Hours/Pound | | | | Twelve Months Ampere Hours/Pound | | | | Eight Mos. Amp. Hr./Lb. |
| BACKFILLS Current Density ma./sq. ft.‡ = | 33 | 50 | 100 | 200 | 33 | 50 | 100 | 200 | 33 |
| 3 Bentonite-1 Gypsum | 245 | 219 | 186 | 309 | 170 | 212 | 296 | 350 | 140 |
| 3 Bentonite-1 Gypsum-1 $Mg(OH)_2$ | 224 | 313 | 205 | 288 | 109 | 245 | 184 | 292 | ... |
| 2 Bentonite-1 Gypsum-1 $Na_2SO_4$ | 134 | 183 | 265 | 274 | 180 | 157 | 233 | 335 | 379 |
| 2 Bentonite-1 Gypsum-1 $Na_2SO_4$-1 $Mg(OH)_2$ | 188 | 88 | 141 | 303 | 186 | 197 | 280 | 279 | ... |
| 1 Gypsum | 303 | 268 | 368 | 233 | 327 | 287 | 362 | 373 | 267 |
| 1 Gypsum-1 $Mg(OH)_2$ | 276 | 283 | 272 | 294 | 213 | 163 | 311 | 313 | ... |
| 3 $Mg(OH)_2$-1 $Na_2SO_4$ | 165 | 219 | 229 | 314 | 182 | 275 | 284 | 342 | ... |
| 199 Bentonite-1 $CrO_3$ | 309 | 286 | 281 | 296 | 249 | 311 | 293 | 318 | 275 |
| 1 Bentonite-4 $MgSO_3$ | ... | ... | ... | ... | ... | ... | ... | ... | 363 |
| 3 Bentonite-1 Plaster of Paris | ... | ... | ... | ... | 113 | 329† | 294† | 408 | ... |

* All efficiencies values are the average for three anodes except as noted.
† Average of six anodes.
‡ Anode current density regulated with resistors.

**TABLE III**

**Performance of 17-Lb. Mg-6%Al-3%Zn Alloy Anodes[1] 50 to 100 ohm/cc Soil[2]**

| | SIX MONTHS | | | | ONE YEAR | | | | TWO YRS. |
|---|---|---|---|---|---|---|---|---|---|
| | Ampere Hour/Pound | | | | Ampere Hour/Pound | | | | Amp. Hr./Lb. |
| BACKFILL Current Density ma./sq. ft.‡ = | 33 | 50 | 100 | 200 | 33 | 50 | 100 | 200 | 50 |
| 3 Bentonite-1 Gypsum | 266 | 523 | 528 | 467 | 392 | 383 | 489 | 514 | 302[2] |
| 3 Bentonite-1 Gypsum-1 $Mg(OH)_2$ | 490 | 274 | 446 | 469 | 394 | 417 | 511 | 570 | ... |
| 2 Bentonite-1 Gypsum-1 $Na_2SO_4$ | 318 | 341 | 448 | 518 | 391 | 442 | 507 | 596 | 339 |
| 2 Bentonite-1 Gypsum-1 $Na_2SO_4$-1 $Mg(OH)_2$ | 421 | 353 | 439 | 464 | 392 | 467 | 497 | 516 | ... |
| 1 Gypsum | 464 | 428 | 353 | 477 | 405 | 488 | 498 | 540 | ... |
| 1 Gypsum-1 $Mg(OH)_2$ | 406 | 446 | 509 | 502 | 397 | 512 | 490 | 505 | ... |
| 3 $Mg(OH)_2$-1 $Na_2SO_4$ | 406 | 425 | 466 | 526 | 417 | 454 | 486 | 566 | ... |
| 199 Bentonite-1 $CrO_2$ | 454 | 578 | 561 | 599 | 410 | 435 | 549 | 555 | ... |
| No Backfill[4] | 216 | 280 | 329 | 450 | 322 | 329 | 409 | ... | ... |
| 1 Bentonite-4 $MgSO_3$ | ... | 437 | ... | ... | ... | ... | ... | ... | 485 |
| 3 Bentonite-1 Plaster of Paris | 254 | 271[3] | 384[3] | 490 | ... | ... | ... | ... | ... |
| 97 Bentonite-3 CaO | ... | 419 | ... | ... | ... | ... | ... | ... | ... |
| 97 Bentonite-3 $SrSO_4$ | ... | 202[5] | ... | ... | ... | ... | ... | ... | ... |
| 75 Bentonite-185 $MgSO_3$-65 Mg $(OH)_2$ | ... | 344 | ... | ... | ... | ... | ... | ... | ... |
| 2 Bentonite-1 Gypsum-1$Na_2S.9H_2O$ | ... | 370 | ... | ... | ... | ... | ... | ... | ... |
| 50 Bentonite-25 Gypsum-65 Mg $(OH)_2$-18.5 $MgSO_3$ | ... | 384 | ... | ... | ... | ... | ... | ... | ... |
| 9 Bentonite-9 Starch-2 Quebracho-NaOH to 12.0 pH | ... | 328 | ... | ... | ... | ... | ... | ... | ... |
| 3 Boroco-1 Gypsum | ... | 382 | ... | ... | ... | ... | ... | ... | ... |
| 3 Zeogel-1 Gypsum | ... | 372 | ... | ... | ... | ... | ... | ... | ... |
| 3 Kaolin-1 Gypsum | ... | 368 | ... | ... | ... | ... | ... | ... | ... |
| 4 Baroid-1 $Na_2$-$SO_4$ | ... | 348 | ... | ... | ... | ... | ... | ... | ... |
| 3 Hectorite-1 Gypsum | ... | 368 | ... | ... | ... | ... | ... | ... | ... |
| 3 Gypsum-1 $Na_2SO_4$ | ... | 377 | ... | ... | ... | ... | ... | ... | ... |

[1] All efficiency values are based on an average of three anodes except as noted.
[2] Freeport installations.
[3] Average of six anodes.
[4] Average of two anodes.
[5] One anode.
‡ Anode current density regulated with resistors.

alloy containing an excessive amount of nickel. The results obtained in this test are shown in Figure 4. The efficiency data shown here are not strictly comparable, since the same backfill was not used in all cases. They do, however, serve to give a general idea as to the effect of these impurities.

Recent laboratory studies, concerned with the effect of copper on the anode efficiency of Mg-6%Al-3%Zn alloy, suggest that the tolerance for copper may depend upon the amount of other impurities present. For example, primary grade alloy having a low overall impurity content may contain up to at least 0.15 percent copper without impairment of anode efficiency. Secondary alloy having the same nominal composition but a substantially higher overall impurity content exhibits an appreciable reduction in efficiency on going from 0.05 to 0.15 percent copper (See Figure 5). These data suggest that impurities normally considered harmless (lead, silicon, tin) may in some instances enhance the injuriousness of impurities which are known to be harmful (nickel, iron, copper). Accordingly, it is unwise to asume that the tolerance levels for nickel, iron, and copper will be the same in an alloy having a high total impurity content as in an alloy having a low total impurity content.

**TABLE IV**

**Performance of 17-Lb. Mg-6%Al-3%Zn Alloy Anodes***

**500 to 1000 ohm/cc Soil**

| BACKFILL | Current Density ma./sq. ft.‡ | SIX TO EIGHT MONTHS Ampere Hours/Lb. 33 | 50 | 100 | ONE YEAR Ampere Hours/Lb. 33 | 50 | 75 | 100 | TWO YRS. Amp. Hr./Lb. 50 |
|---|---|---|---|---|---|---|---|---|---|
| 3 Bentonite-1 Gypsum | | 445(14) | 433(3) | 507(3) | 452(13) | 462(3) | 492(4) | 504(1) | 503(6) |
| 2 Bentonite-1 Gypsum-1 $Na_2SO_4$ | | 382(9) | ..... | ..... | 423(9) | ..... | ..... | 576†(1) | 508(3) |
| 1 Gypsum | | 446(9) | ..... | ..... | 450(9) | ..... | ..... | ..... | ..... |
| 199 Bentonite-1 $CrO_3$ | | 478(9) | ..... | ..... | 470(9) | ..... | ..... | ..... | ..... |
| No Backfill | | 385(2) | 401(2) | ..... | 452(2) | 483(2) | ..... | ..... | ..... |
| 1 Bentonite-4$MgSO_3$ | | 488(5) | ..... | ..... | 526(6) | 526(6) | ..... | ..... | 534(3) |
| Galvo-Pak | | ..... | ..... | ..... | ..... | ..... | ..... | 579†(1) | ..... |

* Numbers in parenthesis indicate the number of anodes taken into consideration in arriving at the particular figure.

† Sixteen months.

‡ Anode current density regulated with resistors.

### Effect of Anode Current Density

Magnesium anode performance is influenced in several ways by variations in anode current density, the most notable of these effects being listed below:

1. Anode efficiency improves with increase in current density for current densities ranging from 0-700 milliamperes per square foot. The extent and rate of increase in efficiency depends upon both the electrolyte and the composition of the magnesium anode. Efficiencies rise rapidly to a maximum of 600 to 650 ampere-hours per pound in the case of the high purity alloys, whereas the efficiency of cell magnesium rises more slowly and attains its maximum efficiency of 500 to 550 ampere-hours per pound only at cur-

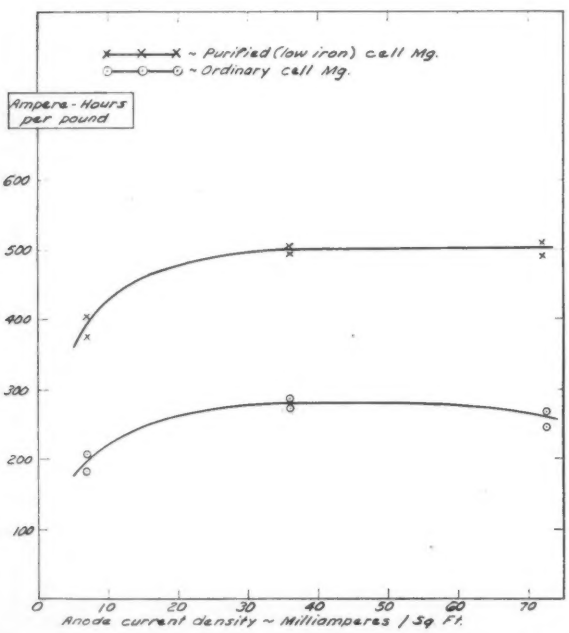



Figure 3—Comparison of performances of ordinary cell Mg and "low iron" cell Mg in 3000-5000 ohm/cc tap water. Laboratory data.

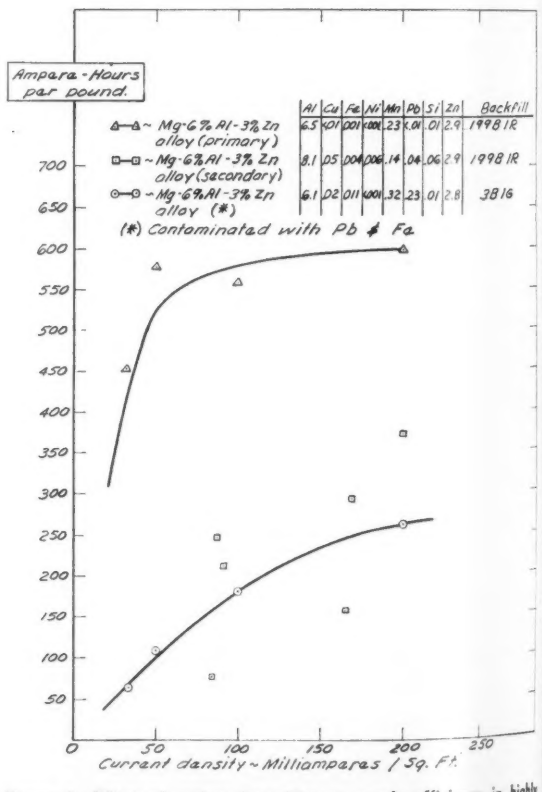



Figure 4—Effect of various impurities on anode efficiency in highly saline soil. Test duration 6 months. Soil resistivity = 100 ohm/cc. Anode current flow regulated with resistors.

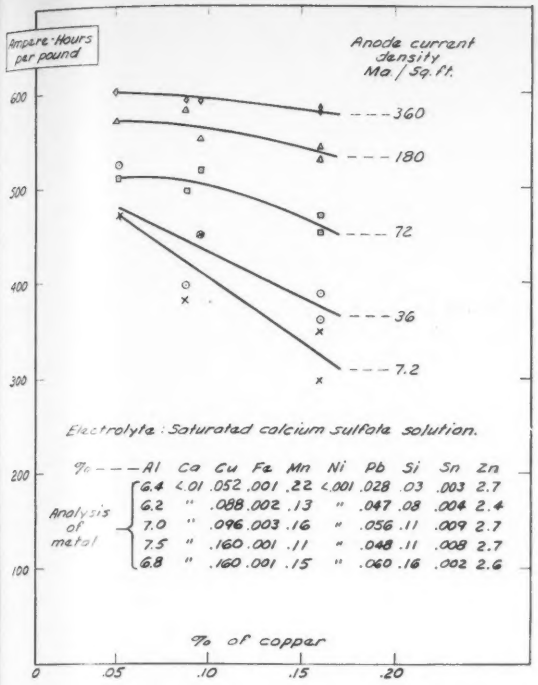

Ampere-Hours per pound
Anode current density Ma/Sq. Ft.
360
180
72
36
7.2
Electrolyte: Saturated calcium sulfate solution.
% Al Ca Cu Fe Mn Ni Pb Si Sn Zn
Analysis of metal
6.4 <.01 .052 .001 .22 <.001 .028 .03 .003 2.7
6.2 " .088 .002 .13 " .047 .08 .004 2.4
7.0 " .096 .003 .16 " .056 .11 .009 2.7
7.5 " .160 .001 .11 " .048 .11 .008 2.7
6.8 " .160 .001 .15 " .060 .16 .002 2.6
% of copper

Figure 5—Effect of copper on the efficiency of Mg-6%Al-3%Zn alloy (secondary) at various current densities. Laboratory pencil test: Saturated $CaSO_4$ electrolyte.

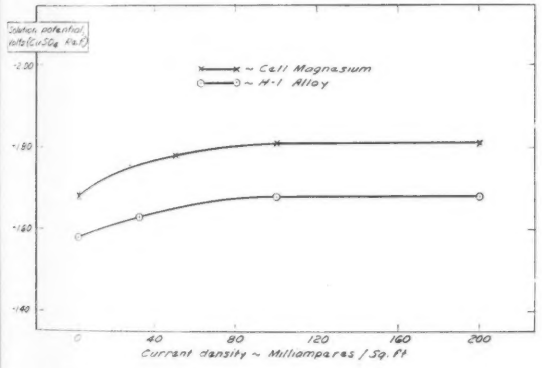



Figure 6—Effect of current density on the solution potential of magnesium anodes as measured with the null circuit. Field tests at Freeport, Texas, in saline soil. Soil resistivity = 125 ohm/cc. Backfill 3B1G.

rent densities in excess of about 700 ma/sq. ft. The general tendency for efficiency to rise with increase in current density is illustrated in Figures 2, 13, 14, and 15. This effect is sometimes obscured by the general scatter of the efficiency data for individual anodes. In field tests a large number of anodes and a wide range of current density must be employed to clearly demonstrate the effect.

2. Magnesium anodes corrode more smoothly at high than at low current densities. At current densities below about 50 ma/sq. ft. the anodic corrosion attack is usually characterized by some pitting and a generally irregular attack. Beginning at about 100 ma/sq. ft. the attack commences to smooth out and for current densities above about 150 ma/sq. ft. is very smooth and regular. The current density at which a smooth corrosion attack sets in will depend to some extent upon the nature of the medium in which the anode operates. For example, a higher current density is needed to get uniform attack in a highly conductive medium, such as sea water, than in a poorly conductive electrolyte, such as a pure gypsum backfill.

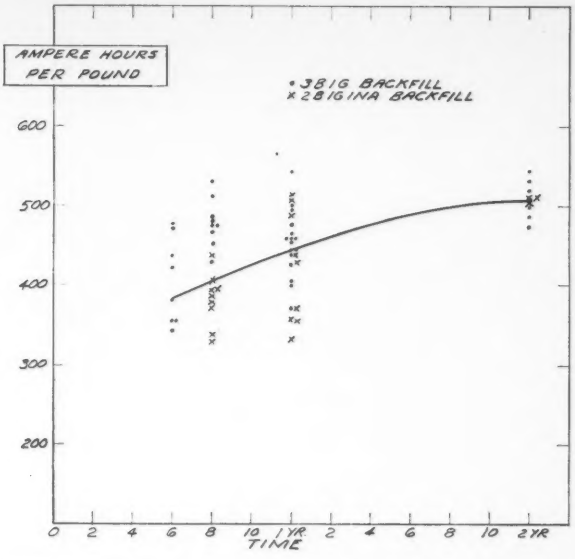



Figure 7—Effect of time on anode efficiency for 17-lb., Mg-6%Al-3%Zn anodes operating in soil at current densities ranging from 30-50 ma/sq. ft. Anode current output regulated with resistors.

3. The potential of the magnesium anode tends to become more anodic with increase in current density when the potential is measured in such a way as to exclude IR drop, e.g., with the Person-Hadley null circuit.[2] This effect is illustrated in Figure 6. These data were obtained by measuring anode potentials, under field conditions and at various current densities, with the null circuit. This particular circuit is designed to eliminate from the measurement the IR drop resulting from the flow of current away from the anode. Measurements made in the conventional way include a portion of the IR drop and give potential values some 0.10 to 0.15 volt lower than these shown in Figure 6. These observations demonstrate the tendency of the magnesium anode to become more active under load.

### Effect of Time on Anode Performance

Observations on anode installations over periods ranging from one to four years show that the pas-

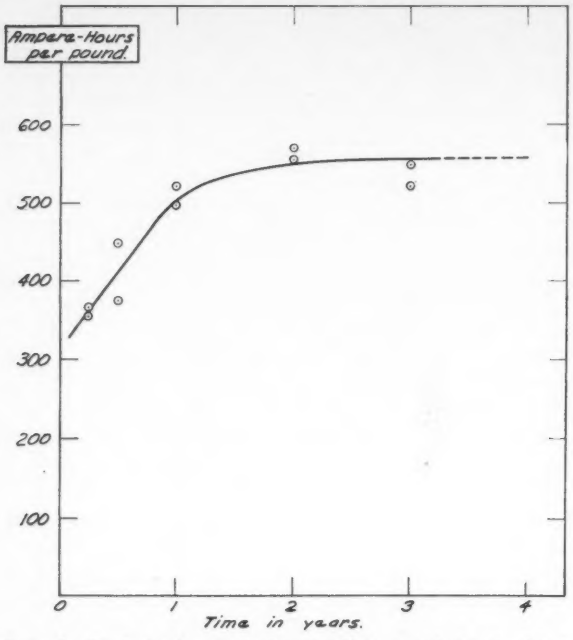



**Figure 8—Graph showing trend of anode efficiency with time for 4-inch diameter x 20-inch, 16 lb. Mg-6%Al-3%Zn anodes operating in a 75 percent bentonite-25 percent gypsum backfill at a constant current of 50 milliamperes. Laboratory drum test.**

sage of time affects anode performance in several ways:

1. Anode efficiency is altered in various ways depending upon the nature of the soil at the site of installation.
2. Backfills are subject to depletion with respect to their soluble components.
3. Anode volume is progressively reduced at a rate which is roughly proportional to the current flow.

1. *Anode Efficiency*

Field experience at both Freeport and Midland is that anode efficiency tends to increase with time over at least the first two years of anode life except for installations in chloride-rich soils. The trend of efficiency with time for anodes operating in a 500 ohm/cc soil (Freeport) is shown in Figure 7. Observations on field installations in the Midland area indicate that efficiencies are usually higher on anodes in service for three to four years than on anodes removed after one to two years. Evidence of this trend is presented in Figures 13 and 14. Additional confirmation of these observations is presented in Figure 8 which shows the increase in efficiency with time for anodes operating at a constant current flow in the laboratory drum test.

The tendency for efficiency to increase with time may be accounted for in several ways. For example, the anode will in time produce its own "backfill" of corrosion products. These naturally formed corrosion products may be conducive to more efficient anode performance than the original backfill in some instances. It is also believed that the aluminum rich chill skin on cast alloy anodes will tend to hold efficiencies down until such time as most of the aluminum-rich areas have been sloughed off by anodic corrosion. Finally, there is a tendency for anode current density to increase with time due to the fact that anode size and area decrease more rapidly than anode current flow as the anode is expended. This would make for some increase in efficiency.

The trend of anode efficiency with time is not always upward but depends to some extent on soil characteristics. In highly saline (chloride-rich) soils, for example, the efficiency of anodes installed with backfill has usually been found to decrease with time in tests covering a two year period. Exceptions to this occur where the anodes are installed without backfill or where the $MgSO_3$-bentonite backfill is used. Data supporting these observations are presented in Table III. The above effect appears to be confined to highly saline soils (100 ohm/cc or less) and is probably due to the migration of chloride ion through the backfill to the anode. The resulting enrichment of corrosion products and backfill with respect to chloride ion is known to be detrimental to anode efficiency. Laboratory experiments in sodium chloride solution support the above explanation.

2. *Leaching of Backfills*

Extensive depletion of backfills with respect to soluble constituents such as gypsum and sodium sulfate has been noted on some anode installations at both Freeport and Midland. Analyses for soluble sulfate on backfills which have been in service for two to four years indicate degrees of depletion ranging from 35 to 95 percent as is illustrated in Table V. Presumably this loss of soluble material is due to the percolation of rainwater and ground waters through and around the backfill over an extended period of time. The data now available do not suffice to fully evaluate the various factors influencing the rate of depletion but scattered observations in the Midland area show that leaching is most severe in well drained, sandy soils, especially on slopes or elevations where drainage conditions are ideal. There is also indirect evidence that the depth of anode burial has an influence on the rate of leaching (See Figure 19b).

Examination of the soil surrounding an anode shows that the conditioning action of the backfill extends out for a distance of some twelve to thirty inches into the adjacent soil, depending upon the particular backfill used. This observation is derived from sulfate analyses and conductivity measurements made on soil samples taken at various distances from the backfill. Data illustrating this effect for two different backfills is shown in Figure 9.

Experience to date has been that the degree of depletion of the backfill, unless extremely severe, does not suffice to indicate how anode performance will be affected. Other factors such as drainage conditions and the nature of the soil must also be considered. Analyses of the soil around field anodes and of their corrosion products has shown that soluble material leaving the backfill usually enters both. If the soluble material entering the soil is swept away rapidly and transported a considerable dis-

tance, both backfill and corrosion products are ultimately exhausted of conducting material and the anode exhibits poor current maintenance. Instances of this have been observed in well drained sandy soils, particularly on slopes. In such cases backfill exhaustion is definitely associated with poor current maintenance.

In poorly drained locations and relatively tight soils substantial depletion of backfills has also been observed to occur but without an adverse effect on current output. In such instances the soluble material diffusing into the soil is probably retained for a long period of time by soil relatively close to the anode. Frequently this effects an increase in soil conductivity and makes for increased current output.

In any soil the loss of soluble backfill components tends to be countered by a migration to the anode of the anions of soluble, ionized material in the soil. This tendency is noted especially in highly mineralized soils where an ample supply of soluble and ionized salts are present. In the case of anodes operating in chloride-rich soils, the analysis of anode corrosion products occasionally reveals an almost complete displacement of sulfate by chloride ion. Although this indicates a high degree of exhaustion of the sulfate backfill, the loss of sulfate is completely compensated by the migration and diffusion of chloride ion inasmuch as current flows are either well maintained or show a tendency to rise. In the poorly mineralized, highly leached soils, the supply of soluble salts is so limited that the counter migration of anions does not compensate for the loss of soluble backfill material and good current maintenance is dependent on the retention of the original backfill salts. When or if the latter is exhausted, the current output falls to about that of an anode installed without backfill.

*3. Reduction in Anode Volume*

It is to be expected that the decrease in anode volume resulting from the gradual consumption of the anode will eventually result in some reduction of current output. The principal question posed here is that of the extent of anode expenditure necessary to bring about a substantial drop in current output. Some field data bearing on this question are available. These data are derived from sixteen and seventeen pound anodes which have been operating at high current flows (300-500 milliamperes) and have been 80-98 percent expended in a matter of two to three and one-half years. Observations on these anodes indicate that current flows are well maintained until the anode is some 70-80 percent expended. Beyond this point, current maintenance falls to values of the order of 60-80 percent, although higher values are occasionally realized. These data are presented in detail in Table VI. Current time logs for two such anodes are shown in Figure 10 and the appearance of these anodes (as compared to a new anode) is shown in Figure 10a. Efficiency data for anodes operating at these higher current densities are presented in Figure 11. Data relating current maintenance to percentage of anode expended are not yet available for anodes operating at substantially lower current flows but it seems reasonable to expect a similar behavior, assuming the absence of other variables.

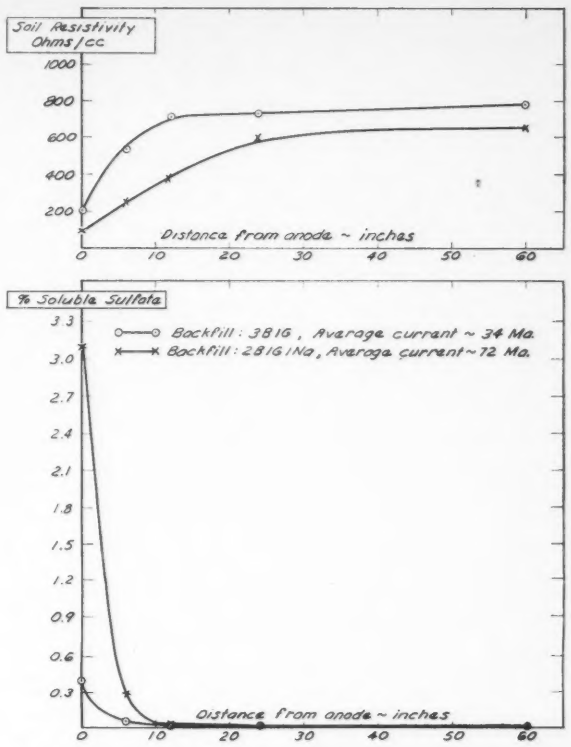



**Figure 9—Conditioning action of backfills on surrounding soil. Backfill in service for 3¼ years when examined. Field test at Freeport, Texas.**

**TABLE V**
**Spot Analysis of Backfill Depletion***

| Anode Location | Backfill | Soil Type | Time in Soil Years | Average Current Drain ma/sq. ft. | Total $SO_4$ Percent | Depletion Percent |
|---|---|---|---|---|---|---|
| A | 2BIGINa | Red Sand | 3.5 | 28 | 5.5 | 82 |
| B | 3BIG | Black Gumbo | 3.5 | 55 | 1.4 | 90 |
| C | 2BIGINa | Black Gumbo | 3.5 | 60 | 20.2 | 35 |
| D | 3BIG | Black Gumbo | 3.5 | 34 | 0.4 | 97 |
| E | 2BIGINa | Black Gumbo | 3.5 | 72 | 3.1 | 90 |

* Texas Installations

## The Effect of Backfill Composition

The practice of using backfills around galvanic anodes has three major purposes:

1. To reduce anode-to-earth resistance and enable the anode to deliver more current per unit of installation.
2. To stabilize the anode potential, prevent polarization, and assure a more dependable source of current.
3. To improve anode efficiency by reducing parasitic corrosion and to bring about a more uniform pattern of corrosion attack at the anode.

For the most part, the above functions form the basis for the evaluation of various backfill compositions, but, as will be evident later, these functions

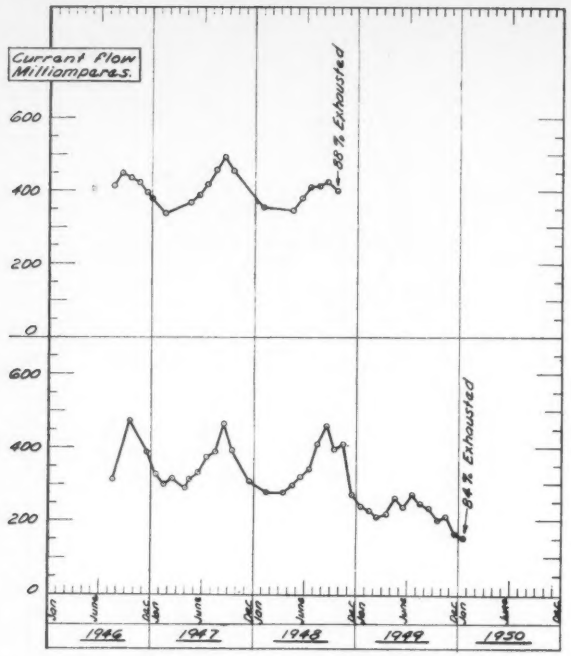



Figure 10—Current time logs for anodes which have operated nearly to exhaustion. Field tests on 16-17 lb. anodes at Midland, Mich. Anode current not regulated.

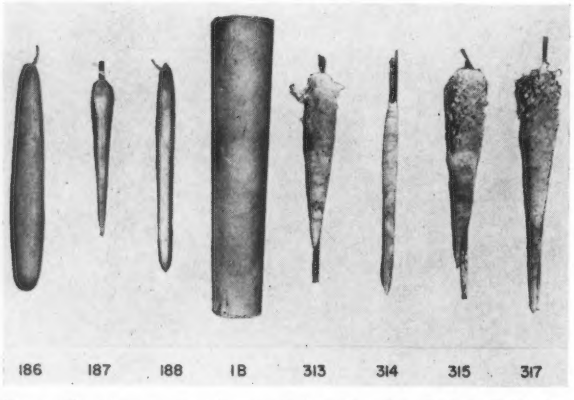



Figure 10a—Appearance of expended anodes described in Table VI. New anode (1B) is shown for comparison. Numbers are anode numbers.

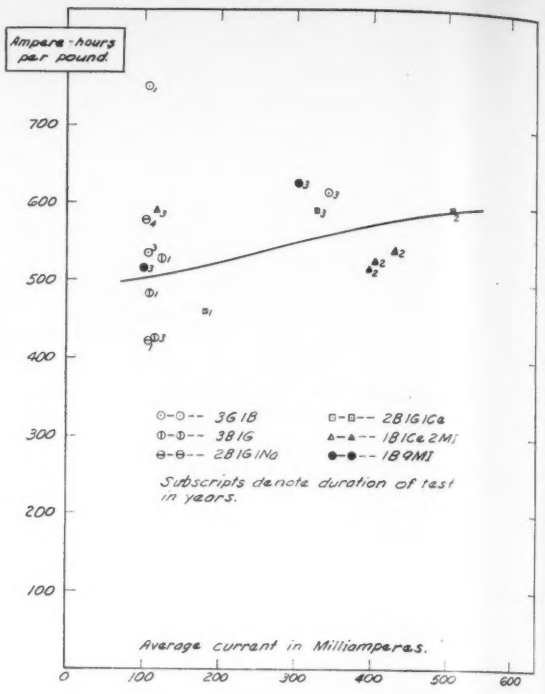



Figure 11—Performance data for Mg-6%Al-3%Zn anodes operating at high current densities and in various backfills. Data taken from field tests on 16-17 lb. anodes at Midland, Mich. Anode current not regulated.

**TABLE VI**

**Current Maintenance vs. Percent Anode Expended**

| Anode Number | Average Current Ma. | Service Life Years | Weight Loss Pounds | Percent Expanded | Percent Current Maintenance |
|---|---|---|---|---|---|
| 186..... | 305 | 3.4 | 14.8 | 84 | 63 |
| 187..... | 327 | 3.4 | 16.4 | 98 | 64 |
| 188..... | 339 | 3.4 | 16.9 | 97 | 62 |
| 313..... | 430 | 2.2 | 14.8 | 91 | 75 |
| 314..... | 510 | 2.2 | 16.0 | 98 | 74 |
| 315..... | 395 | 2.2 | 13.7 | 86 | 72 |
| 317..... | 405 | 2.2 | 14.3 | 88 | 97 |

may sometimes conflict. For example, formulating the backfill to get maximum current output may entail some sacrifice of anode efficiency and vice versa. In addition to the above criteria, backfill life is a pertinent consideration and the achievement of satisfactory backfill stability and life may impose additional limitations on the range of backfill composition which may be employed.

Formulating the backfill to attain maximum performance with respect to any one backfill function does not pose a difficult problem since there are well established relationships between backfill functions and backfill properties. Rather the problem consists in arriving at a formulation which will effect a satisfactory compromise between conflicting backfill functions and yet have good volume stability and adequate resistance to leaching by ground water.

Some of the more important backfill properties include:

*Electrolytic Conductivity*

Conductivity is obtained by incorporating an ionizable compound into the backfill and a wide range of conductivity is possible depending upon the compound selected. For maximum current flow a high conductivity is desirable but this is subject to the limitations that 1) highly soluble, hence readily leachable, material is needed to produce high conductivity and 2) anode efficiency tends to fall off with increase in conductivity unless there is a compensating increase in anode current flow. In general, a high conductivity backfill will provide the highest initial current flows but it is also the most susceptible to depletion by leaching and current maintenance is likely to be poorer than that realized in backfills of lower conductivity.

*Species of Anion Supplied by Backfill*

In one sense backfills are ion reservoirs and can

be made to supply any one of several different species of anion depending upon the ionizable compound used to provide conductivity. It is well established that the potential, efficiency and polarization behavior of the magnesium anode are all strongly influenced by the nature and concentration of its ionic environment. Magnesium is most active and least efficient in a strong chloride electrolyte, most efficient and least active in a medium rich in hydroxyl, fluoride, phosphate or borate ions. Electrolytes supplying sulfate ion provide a practical compromise between the above extremes and have been used extensively in formulating the current backfill compositions.

*Leaching Resistance and Storage Capacity for Water*

Resistance to leaching appears desirable insofar as it extends the life of the ionizable material in the backfill. The need for water storage capacity is indicated in that water is indispensable to good electrolytic conductivity and is required to complete the electrochemical reactions occurring at the anode. In the current backfill formulations these properties are obtained by incorporating into the backfill various "filler" materials. These may be either native clays or various commercial clays such as kaolin and the bentonites. Certain of the bentonites have a large capacity for absorbing water and a high water impedance which enables them to retard the leaching of soluble backfill ingredients by percolating ground waters. Associated with these properties, however, is a pronounced tendency to swell or shrink with gain or loss of water, thereby producing a backfill having poor volumetric stability under field conditions. This feature can usually be controlled, however, either by regulating the amount of clay used or by suitable installation practice.

*Backfill Testing Program*

In the course of the backfill testing some forty different backfill compositions were investigated. A number of these backfills contained the same chemical components and differed only with respect to the proportions in which these components were used. The following is listing of the backfills which differed by at least one chemical component:

1. Bentonite—gypsum (hydrated and calcined)
2. Bentonite—magnesium sulfite (hydrated)
3. Bentonite—gypsum—sodium sulfate (anhydrous)
4. Bentonite—gypsum—magnesium hydroxide
5. Bentonite—gypsum—sodium sulfate—magnesium hydroxide
6. Bentonite—lime (CaO)
7. Bentonite—strontium sulfate
8. Bentonite—magnesium sulfite—magnesium hydroxide
9. Bentonite—gypsum—magnesium sulfite—magnesium hydroxide
10. Bentonite—gypsum—sodium sulfide
11. Bentonite—chromic acid
12. Bentonite—starch—sodium hydroxide—Quebracho
13. Magnesium sulfite—magnesium hydroxide
14. Gypsum
15. Gypsum—sodium sulfate
16. Gypsum—magnesium hydroxide
17. Sodium sulfate—magnesium hydroxide

In some of the above compositions the bentonite was partially or wholly replaced with other filler materials in order to check the influence of the "filler" on anode performance. Included among these materials were Texas bentonite (as distinguished from Wyoming bentonite), attapulgite, hectorite, barium sulfate, kaolin, Celite, Boroco, Zeogel and Baroid. In general, no one of these materials proved to be significantly superior to any other.

*Anode Efficiency*

With the possible exception of the backfills rich in sodium sulfate (2B1G1Na, 1G1Na), good efficiencies (500 amp. hr./lb.) are realized after two to three years of service in almost all of the above backfills with Mg-6%Al-3%Zn anodes operating at current drains corresponding to ten year life or less. The major exception to this occurs where installations in highly saline, chloride-rich soils are involved. Because of the effect of time, discussed previously, the influence of backfill on anode efficiency is most pronounced during the first six to eighteen months of service. During this period there is a gradual rise in anode efficiency (except in high chloride soils) and thereafter efficiencies show a tendency to equalize regardless of backfill composition as shown in Figure 7.

Despite the trends noted above, certain of the backfills tested are productive of significantly higher efficiencies than others even after an extended period of service. Data from all sources point to the bentonite-magnesium sulfite compositions (1B9MI and 1B4MI) as being appreciably better in this regard. In field tests at Midland, alloy anodes operating in this backfill consistently exhibit efficiencies in the 500-600 amp. hr./lb. range after three years of service as shown in Figure 14g. In the 500-1000 ohm/cc soil at Freeport, similar results are obtained after one and two years on test as shown in Table IV. It is noteworthy that this backfill is the only one to produce and maintain a reasonably high efficiency for a period of two years in the highly saline (50-100 ohm/cc) soil at Freeport (See Table III).

Backfill efficiency ratings based on the laboratory drum test procedure are shown in Figure 12. This particular test shows the bentonite backfills having $MgSO_3$ or gypsum as the major component to have the highest efficiency ratings whereas the bentonite-gypsum-sodium sulfate composition (2B1G1Na) has distinctly the poorest rating. The various other backfills tested fall into an intermediate bracket. It is well to note that the laboratory drum test is a short term test (six months) which is likely to reveal greater differences between backfills than would be realized on a test of two to three years duration.

The efficiencies obtained in the field tests of various backfills at Midland are shown in Figures 13, 14, and 15. The data presented here are for test

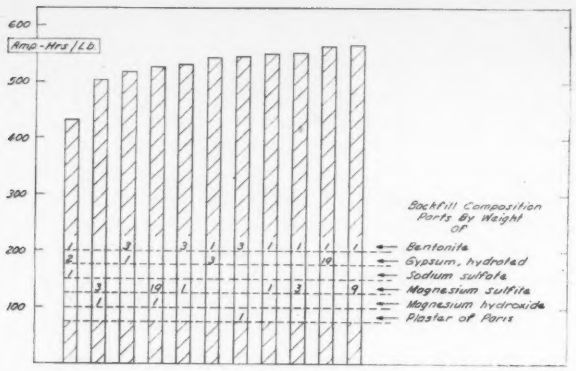
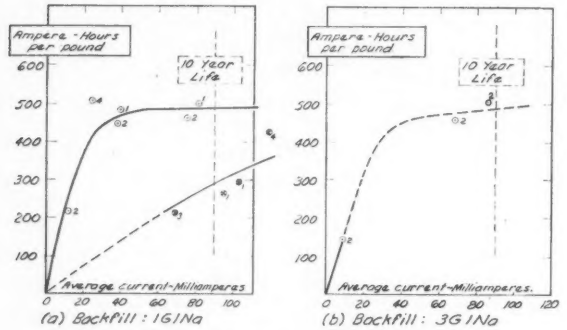



**Figure 12—Performance of Mg-6%Al-3%Zn anodes in various backfills. Six months' test on 4-inch diameter x 20-inch 16-lb. anodes under simulated field conditions. Current flow held constant at 100 milliamperes for all anodes tested and 2-3 anodes tested in each backfill composition. Laboratory drum test.**



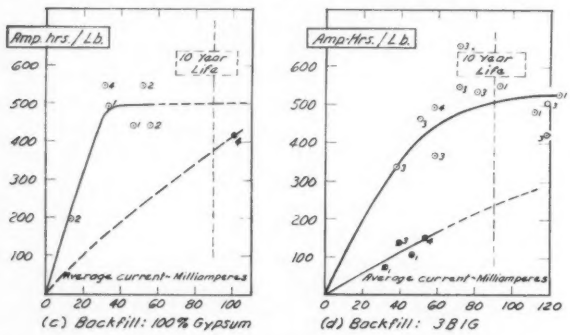




**Figure 13—Performance of Mg-6%Al-3%Zn alloy and cell magnesium anodes in various backfills. Data derived from field tests on 16-17 lb. anodes at Midland, Mich. Subscripts denote duration of tests in years. Anode current note regulated.**

periods ranging from one to four years. A fair degree of correspondence is noted between the laboratory drum tests and the field tests as regards efficiency ratings. As in the drum tests, the $MgSO_3$-bentonite backfill is best, followed closely by the pure gypsum and gypsum-rich bentonite (3G1B) backfills, in which efficiencies reach a high level at relatively low current densities. The sodium sulfate backfills appear to be a slightly less efficient medium than the compositions cited above.

The data from field tests on various backfills at the Freeport site are presented in Figure 16 and

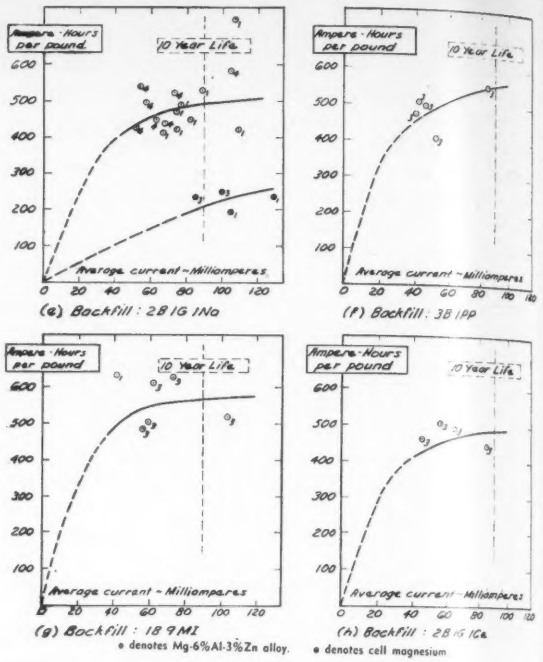



**Figure 14—Performance of Mg-6%Al-3%Zn alloy and cell magnesium anodes in various backfills. Data derived from field tests on 16-17 lb. anodes at Midland, Mich. Subscripts denote duration of test in years. Anode current not regulated.**

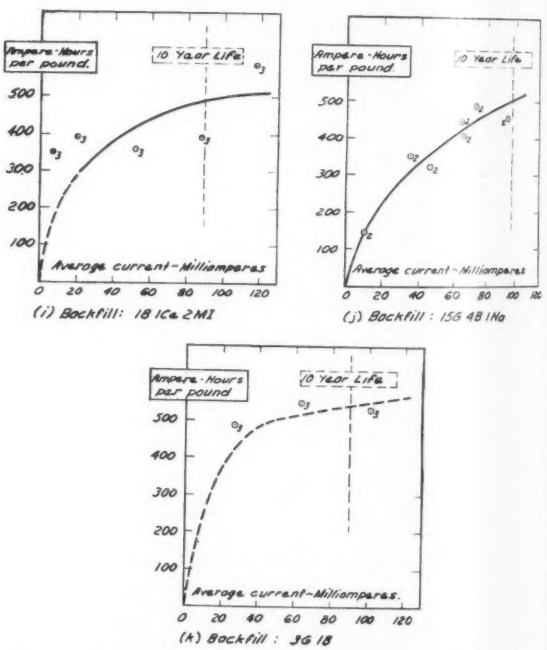

Ampere-Hours per pound.
10 Year Life
Average current-Milliamperes
(i) Backfill: 18 1Ca 2MI
(j) Backfill : 1SG 4B 1Na
(k) Backfill : 3G 1B

**Figure 15—Performance of Mg-6%Al-3%Zn alloy anodes in various backfills. Data taken from field tests on 16-17 lb. anodes at Midland, Mich. Subscripts denote duration of test in years. Anode current not regulated.**

in Tables II, III, and IV. In the one-year test (Figure 16) the magnesium sulfite-bentonite backfill (1B4MI) is again outstanding, the next best backfill being the bentonite-chromic acid composition

(199B1R). The 2B1G1Na backfill again has the lowest efficiency rating while the pure gypsum and bentonite-gypsum backfills (3B1G) occupy an intermediate position, comparable to that of anodes installed without backfill. In the two-year tests in 500-1000 ohm/cc soil (Table IV) the magnesium sulfite-bentonite mixture continues to afford the best anode efficiency, while the 2B1G1Na composition is now slightly more efficient than the 3B1G backfill. The performance of various backfills in the highly saline soil is shown in Table III. As previously noted, the magnesium sulfite-bentonite backfill has the best two-year performance record in this soil. The behavior of the bentonite-chromic acid backfill (six-month test) is also noteworthy in that it demonstrates the beneficial effect of chromate in a saline soil. Unfortunately, the effect is not well sustained (See one-year test data). The performance of cell magnesium anodes in various backfills is shown in Table II.

The magnesium sulfite backfills described above are as yet experimental compositions for several reasons, a major one being that magnesium sulfite is not now available in commercial quantities. While it can be manufactured readily from relatively cheap raw materials, its cost relative to gypsum is yet to be determined. Because of its solubility (about 5x that of gypsum) and its susceptibility to oxidation, there is also some question as to its stability in storage and in service. Accordingly, the adoption of $MgSO_3$ as a standard backfill ingredient must await an evaluation of these factors.

*Current Output*

Except in soils of very low or very high resistivity, the use of a backfill can be expected to produce a substantial increase in anode current flow. Evidence of this is presented in Figures 16 and 17 where the current flows from anodes installed in several different backfill compositions are compared with the output of anodes installed without backfill. These illustrations also show, as would be expected from conductivity considerations, that the extent of the increase in current flow depends upon backfill composition. In general, the backfils having the best conductivities, e.g., 2B1G1Na and 1B4MI, produce a greater increase in current flow than those having poorer conductivity such as the 3B1G and pure gypsum backfills. The wide fluctuations in the output of the backfilled anodes of Figure 17 are due primarily to variations in rainfall and ground moisture levels. Deeper installation would have rendered the output less sensitive to seasonal variations in rainfall.

*Current Maintenance*

Backfill composition is one of the several factors affecting the maintenance of anode current flow over an extended period of time. The data presented in Figures 18 and 19a illustrate the differences observed between various backfills as regards current maintenance in studies covering a two to four year period. These data essentially indicate that backfills

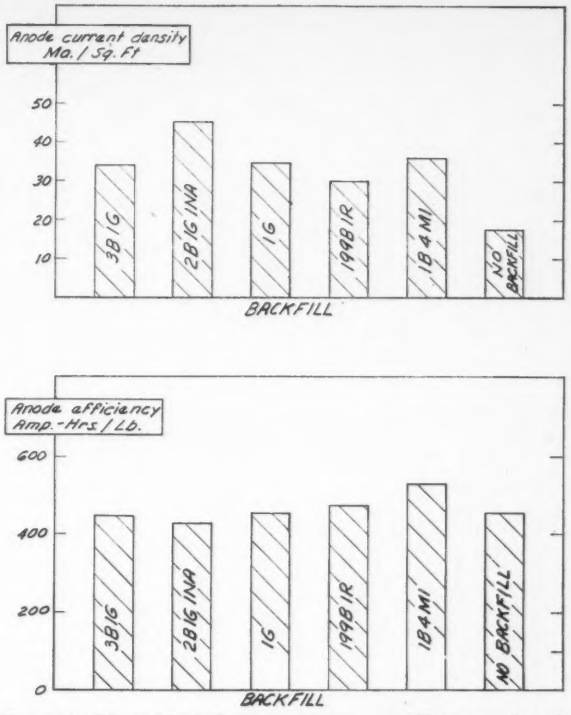



**Figure 16—Effect of backfill composition on anode efficiency and anode current output based upon 1-year test of 17-lb. Mg-6%Al-3%Zn anodes operating in 500 ohm/cc soil. Test data taken from 51 anodes. Anode current not regulated.**

of relatively low solubility and poor conductivity, such as pure gypsum and the 3G1B composition, will provide better current maintenance, especially at the lower current flows. The above data may appear to imply that current maintenance is poorest at the lowest current flows. Actually this is a somewhat superficial relationship. The low current flows are indicative of high resistivity soil which, at this particular installation site, is sandy and exceptionally well drained. This results in rapid leaching of the more soluble, highly conducting backfills thereby reducing backfill conductivity and anode current flow. The practical significance of this data is that the backfills containing highly soluble material cannot be expected to maintain current flows at their initial levels for very long in well drained soils. Less soluble backfills will give a lower initial output but better current maintenance. In many such soils it will be still more practical to employ an anode especially adapted to low resistance soil (cored ribbon or rod) and dispense with the use of backfill entirely.

## Backfill Preparation and Installation Practice

At least three different methods of installing backfills are currently being practiced:

1. Installation as a wet mud or slurry.
2. Installation as a dry premixed powder followed by natural or artificial wetting.
3. Installation of both anode and backfill as a single packaged unit in which the anode is completely surrounded by backfill. The backfill may be either the usual type or especially compounded for quick-wetting (Galvo-Pak).

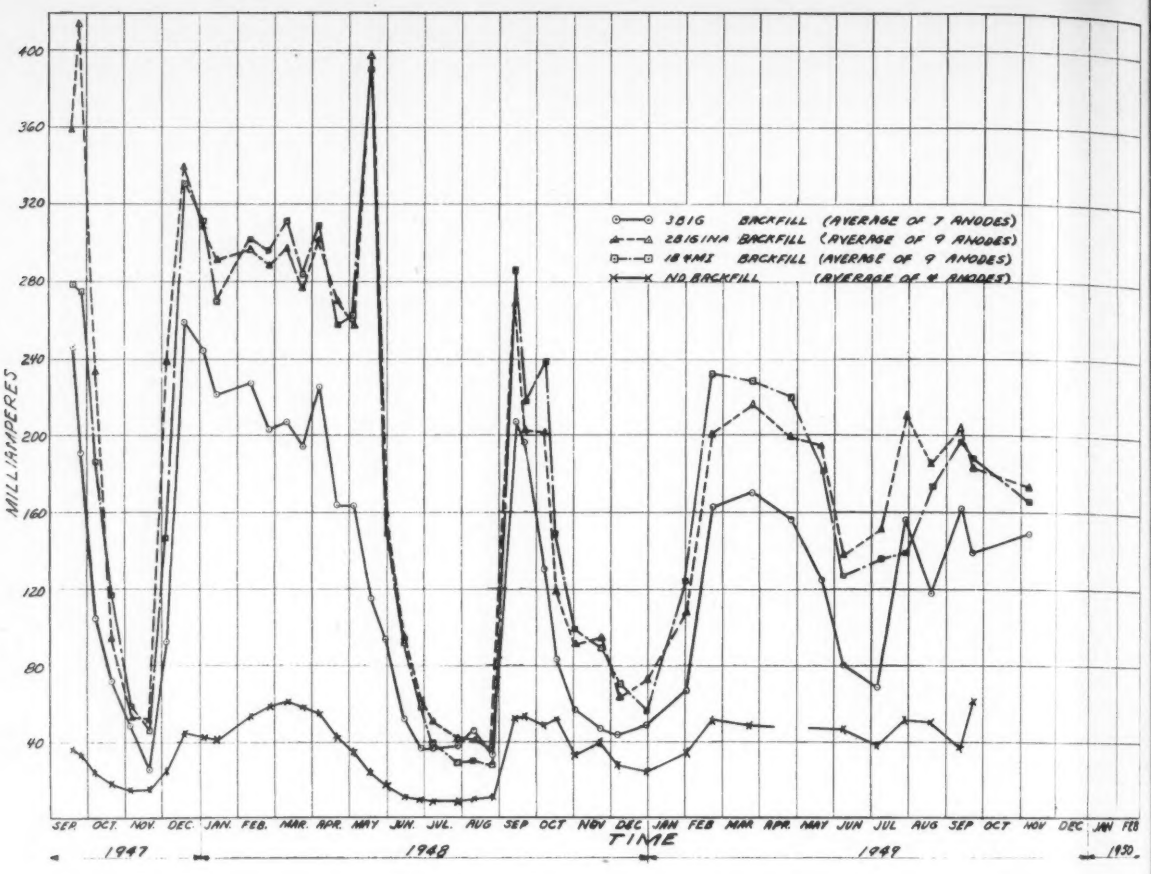

MILLIAMPERES
TIME
3B1G BACKFILL (AVERAGE OF 7 ANODES)
2B1G1NA BACKFILL (AVERAGE OF 9 ANODES)
1B9MI BACKFILL (AVERAGE OF 9 ANODES)
NO BACKFILL (AVERAGE OF 4 ANODES)
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB
1947
1948
1949
1950

Figure 17—Comparison of current flows from 17-lb. Mg-6%Al-3%Zn anodes operating in various backfills and without backfills. Soil resistivity = 500 ohm/cc. Hole depth 60 inches.

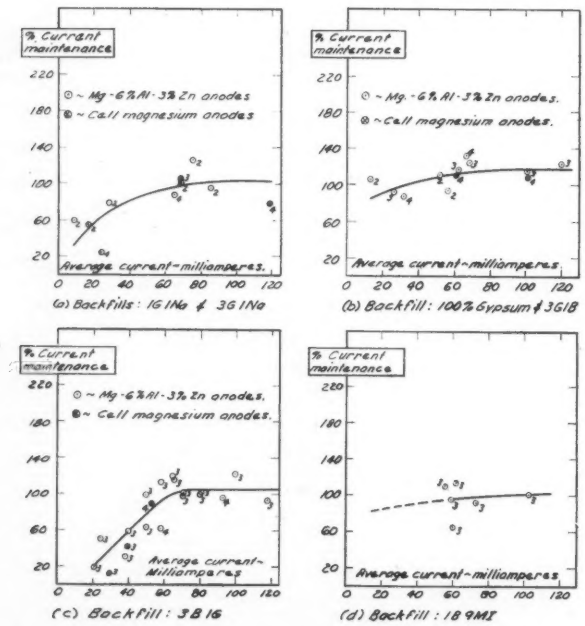
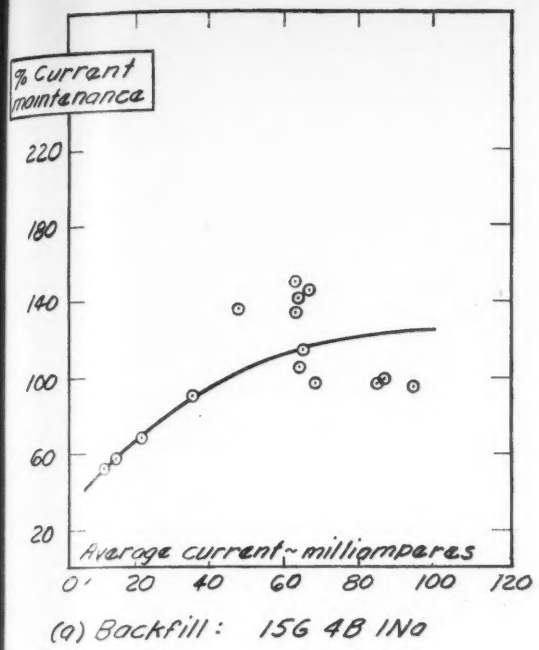



Figure 18—Observed relation of current maintenance to magnitude of anode current in various backfill compositions. Data taken from field tests on 16-17 lb. anodes at Midland, Mich. Subscripts denote duration of test in years. Anode current not regulated.

Experience has shown that the performance of the magnesium anode, relative to both current output and maintenance of current flow, is markedly influenced by the choice of installation practice. This is especially true for the backfills having bentonite as the major component (3B1G) inasmuch as these backfills are subject to pronounced swelling or shrinkage with fluctuations in ground moisture levels. If installed as a wet mud, they exhiibt a tendency to shrink and lose contact with either anode or earth during periods of scanty rainfall with an attendant reduction in anode current flow. This condition is eventually remedied as the corrosion products increase in volume and commence to exert pressure, but considerable time may elapse before this occurs and current flows become stabilized.

The above difficulty with the high bentonite backfills can be controlled either by going to deeper holes or by installing the backfill as a dry powder and depending upon ground water for wetting. The latter practice permits the introduction of more material and results in a backfill which is under pressure at practically all ground moisture levels. The net effect on anode performance is to produce a higher and more stable current flow than is obtained with the same backfill installed wet. The improvement is especially noticeable in well drained soil as is shown



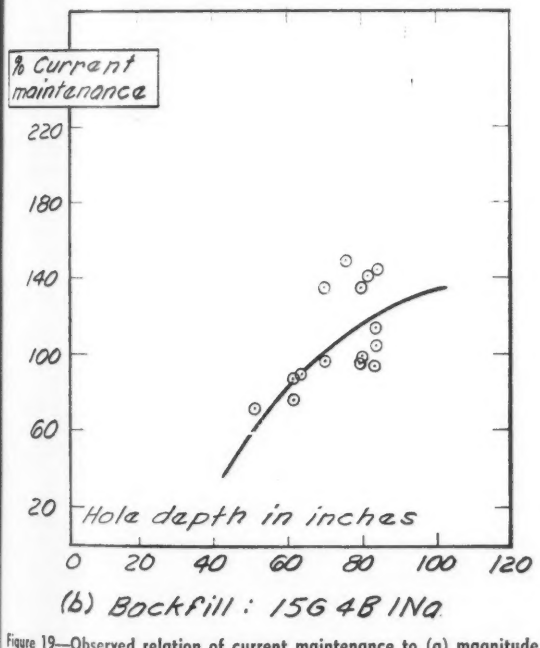




**Figure 19—Observed relation of current maintenance to (a) magnitude of current flow and (b) depth of anode. Data derived from two-year field tests on 16-17 lb. anodes at Midland, Mich. Anode current not regulated.**

in Figure 20. The principal disadvantage of this practice is that a period of one to two months may elapse before the backfill is thoroughly wetted and full current output is realized.

The packaged anode (Galvo-Pak) offers a compromise between the above alternatives. The backfill in this case is a low bentonite-high gypsum composition which wets rapidly and will deliver its maximum current output within a few minutes if

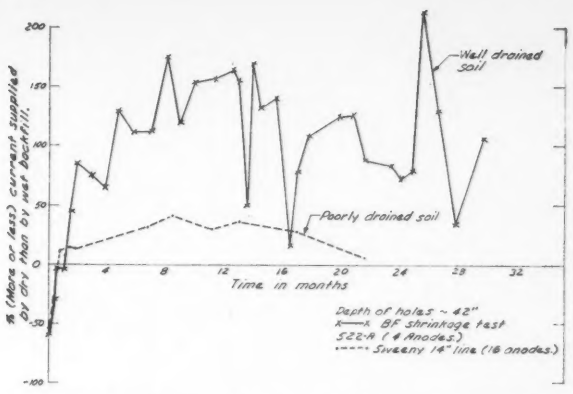



**Figure 20—Current output of anodes installed with dry backfill relative to anodes installed with wet backfill. 3B1G backfill used in all tests.**

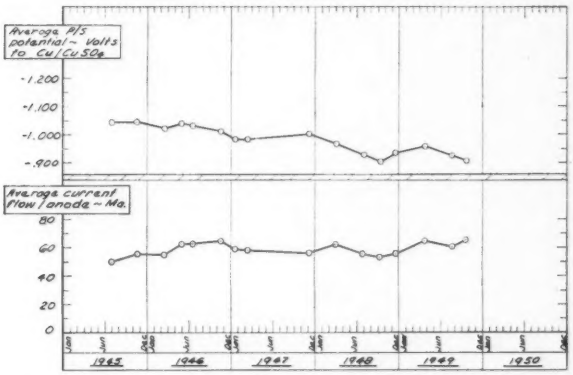



**Figure 21—Performance of magnesium anodes on 80 miles of coated gas line. Installation comprises 84 anodes distributed over 13 stations. Depth of anode burial = 5-8 feet. P/s potentials are average of readings both opposite anode stations and at mid-points.**

wetted at the time of installation. Being low in bentonite and containing a small amount of sodium sulfate it is subject to a minimum of shrinkage or swelling with changes in moisture levels. Experience to date indicates it to be a stable performer.

Depth of installation is also a variable which significantly affects anode performance, particularly with respect to current stability and current maintenance. In the Midland area anodes installed in holes less than about 50 in. to 60 in. deep show extreme fluctuations in current flow with changes in weather and rainfall as compared with anodes installed 70 in. to 90 in. deep. There is also evidence that current maintenance improves with increasing depth of anode burial as indicated by Figure 19b. Experience at both test sites suggests that anode current flow increases with increasing depth of installation although this will obviously depend somewhat on the resistivity of the deeper soil strata.

## General Observations

Observations covering three to four years on some 150 anodes installed in the Midland area indicate that the overall ampere-year output from a large anode installation is likely to be quite constant from year to year until the anodes approach exhaustion.

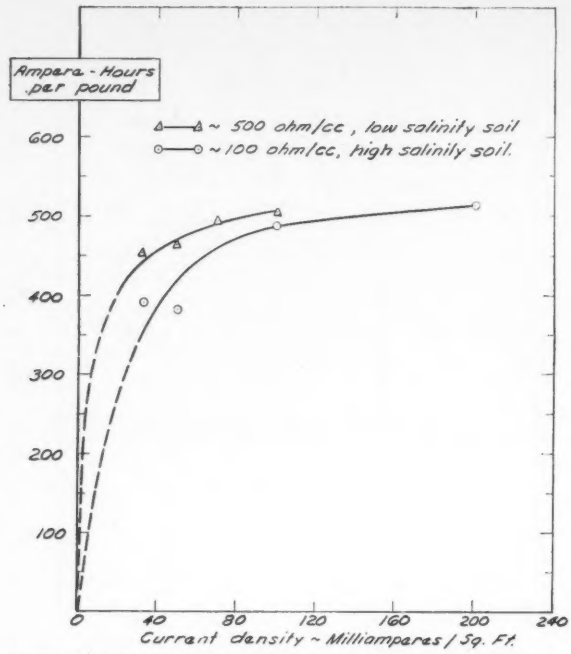



**Figure 22—Effect of soil salinity on performance of 16-17 lb. Mg-6%Al-3%Zn anodes. One year tests at Freeport, Texas, in 3B1G backfill. Anode current regulated with resistors.**

In such an installation the current flow from some anodes is fairly constant from year to year, others show poor current maintenance but this is compensated for by the remainder whose current output tends to increase with time. As a result, current maintenance for the installation at large approaches 100 percent. These observations apply to anodes installed at regular intervals along bare pipe lines without exercising any selectivity as to the type of soil in which anode burial is made. Individual anode current flows in these installations ranged from 40 to 100 milliamperes.

Similar observations are presented in Figure 21 for a group of eighty-four anodes coupled to eighty miles of coated pipe line terminating at the Freeport test site. This installation also exhibits good current maintenance. At the end of four and one-half years, current flows appreciably exceed the initial output due to the slow decrease in coating resistance and the gradual fall of the P/S potential.

Where seasonal temperature changes are large, as at the Midland, Michigan test site anode current flows undergo a pronounced and consistent seasonal fluctuation. Current outputs rise to a maximum in late summer or early autumn and fall to a minimum in late winter as indicated by the current-time logs shown in Figure 1. These oscillations are associated with seasonal changes in soil temperature, soil conductivity and P/S potential.

## Summary

The performance of magnesium galvanic anodes in various backfills and in several different soils has been studied in tests of one to four years duration at two widely separated test sites. Anode performance is found to be affected by several variables, notably anode composition, time, backfill composition, current density and soil characteristics.

Of the anode compositions tested, the high purity Mg-6%Al-3%Zn alloy exhibits the most consistently efficient performance. At current flows equivalent to ten-year life or less, this alloy will usually deliver 500 ampere-hours per pound, except for installations in chloride-rich soils where special backfills or higher current densities are required to get comparable efficiencies. A low impurity content, especially of nickel, iron and copper, is essential to the realization of good anode efficiency. Pure commercial (cell) magnesium anodes develop a higher potential than the alloy anodes but statistical data show their efficiency to be decidedly inferior to that of the high purity alloy.

Anode performance is influenced by time in service in that corrosion products form, backfills are subject to depletion by leaching and the anode steadily diminishes in size as it is expended. Anode efficiency is found to increase with time in service for periods of up to two years except for installations in chloride-rich soils (100 ohm/cc or less). Backfills are subject to extensive depletion by leaching over periods of three to four years but anode current output is not adversely affected except at unusually well drained sites where exhaustive leaching occurs. Anode current flow is well maintained until the anode is 70 to 80 percent consumed at which point current flows drop to 60 to 80 percent of initial output.

Field tests show that both anode efficiency and uniformity of corrosion attack improve with increasing current density as previously indicated by laboratory data. Potential measurements made with the Pearson-Hadley null circuit show magnesium anodes to become more anodic with increasing current density.

The high purity alloy anodes exhibit their highest efficiencies in the magnesium sulfite-bentonite backfills, this composition being particularly effective in highly saline soils. Efficiency-wise, the pure gypsum and high gypsum-low bentonite backfills are also very good while the backfills containing sodium sulfate are relatively poorest, though not markedly so. Backfills containing chromic acid boost anode efficiency substantially in saline soils but the benefit is relatively temporary.

The use of a backfill is found to give a large increase in anode current flow as compared to anodes installed without backfill. The backfills containing sodium sulfate produce the greatest increase in current, followed by the magnesium sulfite-bentonite, bentonite-gypsum, gypsum-bentonite and pure gypsum backfills in approximately that order. Conductivity measurements and soil analyses show that backfills effect conditioning of the soil at some distance beyond the backfill.

Backfills of relatively low solubility and conductivity, such as the pure gypsum and high gypsum-low bentonite compositions, are productive of the best anode current maintenance, especially in well

drained soils. Backfills containing highly soluble salts, such as sodium sulfate, give higher initial current flows but are unable to maintain the initial output for very long in well drained soils because of rapid leaching. The latter backfills function best in tight, poorly drained soils.

The bentonite-rich backfills are highly moisture sensitive and tend to contract or expand excessively with fluctuating ground moisture levels. If installed wet they may shrink enough to drastically reduce current flow during dry periods. The dry installation of such backfills makes for a higher and more stable current output, especially in well drained soils.

Considerations of cost, general availability and the performance characteristics cited above, point to the gypsum-rich bentonite and pure gypsum compositions as being the best general purpose backfills presently available. The magnesium sulfite compositions, while definitely affording better anode efficiency, are still in the development stage and must be checked with regard to stability and cost before being made available. The backfills having sodium sulfate as a major component will continue to be useful backfills so long as their limitations are recognized.

Excellent maintenance of current flow has been observed over periods of three to five years on large groups of anodes. For individual anodes the most stable current flows are associated with deep installations and poor to fair soil drainage. In chloride-rich soils, anode current output tends to rise with time. Poor current maintenance is associated with installations in sandy, well drained soils, especially on slopes or elevations.

### References

1. Magnesium Anodes for the Cathodic Protection of Underground Structures. H. A. Robinson *Corrosion*, **2**, No. 4, 119-218 (1946) Oct.
2. Null Methods Applied to Corrosion Measurements. J. M. Pearson. *Trans. Electrochem. Soc.*, **81**, 485 (1942).

## DISCUSSION

**Comment by David Hendrickson, East Bay Municipal District, Oakland, Cal.:**

Magnesium anodes have not given complete protection for 65-inch diameter steel pipe. This pipe is wrapped with an asphalt impregnated felt. The corrosion was reduced about 50 percent by coupon test. Ten anodes were installed 10 feet apart and 10 feet out from the pipe line. The coupon was attached to the pipe about the center of the anode bed about one foot from the pipe at spring line. The magnesium anodes were replaced with a selenium rectifier and graphite anodes.

**Authors' Reply:**

We do not feel that the above conclusion is warranted on the basis of Mr. Hendrickson's test alone, especially where coated pipe is involved.

If the test above was carried out on a long length of pipe a rather large fraction of the anode current would flow to pipe outside the test section thereby giving a distorted impression both as to the effectiveness at the test site and the number of anodes required to protect the entire line. These are factors which must be considered in evaluating the above test data. It is well also to note that the maximum pipe size which can be effectively and economically protected is largely dependent on soil resistivity and the condition of the coating. (H. A. Robinson.)

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# Chlorinated Rubber Corrosion-Resistant Coatings*

By F. K. SHANKWEILER, G. N. BRUXELLES and R. E. WHITNEY*


## Abstract

Industrial experience during the past fifteen years has shown that chlorinated rubber is an outstanding film-forming material from which corrosion-resistant coatings may be formulated.

Correct formulation has a marked beneficial effect on resistance of chlorinated rubber systems to corrosive solutions or atmospheres. For maximum chemical resistance the types of modifiers for chlorinated rubber are restricted to chemically inert resins and plasticizers which must be formulated properly to give optimum film properties and satisfactory weathering resistance.

If proper precautions in selecting the modifying components are not considered, corrosion resistance of chlorinated rubber coatings may be seriously impaired. For example, alkali resistance rapidly diminishes when the vehicle is modified with saponifiable resins or plasticizers. Similar deficiencies develop if components are incorporated which are not themselves unaffected by acids or salts.

Pigmented coatings in which the film consists of 50-60 percent chlorinated rubber, 15-20 percent Arochlor 5460, Chlorowax 70 or hard coumarone resins, etc., and 25-30 percent Clorafin 42-S, Arochlor 1254 or Cumar P-10, etc., are shown to provide highly effective protection to corrosion. Panels with such coatings tested in the salt fog (ASTM B-117-44T, 20 percent sodium chloride, 100° F) and in tap water immersion (100° F) in comparison with many other types of coatings illustrate their value when exposed to salt corrosion or water.

Because best performance cannot be obtained without suitable primers, a comparison of chlorinated rubber and other types of primers was undertaken in these tests. It is shown that pigmentation of chlorinated rubber primers is equally as important as that previously established with other vehicles. When properly formulated with corrosion-resistant pigments, chlorinated rubber primers together with chlorinated rubber topcoats afford a high degree of protection.

Numerous case histories of commercial use in varied maintenance problems where chemical resistance is essential establish the economical merit of such coatings. Among the fields discussed are acid plants, paper mills, water works, industrial machinery, sewage disposal plants and concrete construction protected by chlorinated rubber.

One feature of chlorinated rubber coatings has led to their acceptance for industrial maintenance. They are applicable by brushing or spraying to surfaces which cannot be physically prepared by ideal procedures. Chlorinated rubber, like most coatings, gives best results over rust-free, clean metal to which efficient primers are applied. The outstanding feature of chlorinated rubber, however, is that it affords reasonably good protection over many types of undercoats or over poorly prepared surfaces.


THE SEVERAL REASONS for interest in chlorinated rubber corrosion-resistant coatings at this time are both general and specific. Generally, those who are charged with the responsibility of selecting corrosion-resistant coatings for maintenance seek information concerning all types of the available materials with a view to placing those materials in the proper category, especially as far as their own corrosion problems are concerned. The problem of using a given coating only for the proper application is one which should be shared mutually by the raw material producers, the protective coating manufacturers and particularly, the users of corrosion-resistant coatings. That this concept is shared by NACE is obvious from the definition of its purpose.

Specifically, interest in the subject comes about by a change in the thinking of industry. In years gone by common practice was to apply an inexpensive coating and if it disintegrated, to apply it as often as required. With extensive increases in the cost of labor, industry has begun to realize that expensive coatings may actually prove to give the lowest maintenance costs by virtue of their longer life. The establishment of groups within consumer companies to study corrosion problems is a current trend which makes a consideration of corrosion-resistant coatings especially timely.

Although chlorinated rubber has had an industrial history of fifteen years in this country and even a longer commercial history in Europe as a corrosion-resistant coating, a need still exists for a better understanding of the effect of formulation on the corrosion resistance and other properties of such coatings.

In the first place, chlorinated rubber is a film-forming material which is soluble in solvents such as xylene, Hi-flash naphtha, and a similar host of aromatic hydrocarbon solvents made by the petroleum and coal tar industries. Chlorinated rubber coatings dry by evaporation of the solvent, which leads to one basic reason for their wide use—the speed with which they dry. Instances wherein chlorinated rubber have been used because of the minimum time of disturbance to plant processes are legion.

Chlorinated rubber, dissolved in solvent and containing pigments for color but not containing other modifying agents, is not of general commercial sig-

★ A paper presented at the Seventh Annual Conference and Exhibition, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.

* All of Hercules Powder Company, Wilmington, Del.

nificance. Chlorinated rubber must be modified with resins (for proper adhesion and high gloss if desired) and with plasticizers (for flexibility and toughness). The wide compatibility of chlorinated rubber with resins and plasticizers has led to its wide industrial use beyond the scope of corrosion-resistant coatings. While compatibility is a tremendous advantage in developing coatings for widely diversified applications, choice of modifiers for corrosion-resistant coatings must be restricted to include only those materials which are themselves unaffected by the exposure medium.

If resins and plasticizers known to be chemically inert are selected, films may be made which are nonreactive to corrosive elements. On the other hand, if, for example, resins or oils known to be saponifiable are included in such compositions, serious degradation occurs upon exposure to alkalies.

A typical chlorinated rubber-resin composition which will saponify is chlorinated rubber and an alkyd resin. Such coatings have extremely good durability when exposed to weather or certain kinds of mild corrosive influences. Results of a test of such coatings is shown by Figure 1. If such coatings are exposed to caustic for several hours or at least more than one day, chemical breakdown occurs. Useful as they are for many industrial applications, they do not have the maximum chemical resistance of concern in this paper.

Where maximum resistance to acids, alkalies, salt and corrosive elements is desired, chlorinated rubber coatings must employ suitable resins and plasticizers. The choice of resins should be limited to the solid types of chlorinated biphenyls, chlorinated paraffins, coumarone—indene resins, etc. Similarly the plasticizers should be inert and may be the liquid or balsamic materials of the same chemical type. Other resins and plasticizers are available but the selection of both should be made with the knowledge that the coating is best formulated if all of the components are inert to chemicals to which the coating is to be exposed.

Experience indicates that the general range of composition useful in chemically resistant maintenance coatings using normal pigment ratios is as follows:

| | |
|---|---|
| Chlorinated Rubber | 50-57.5% |
| Resin | 15-20% |
| Plasticizer | 25-30% |

This general type of coating has been used successfully for years, but two features which appear to be of minor importance actually are of major significance. First, the replacement of only 15 percent of the inert plasticizer with a highly efficient plasticizer such as dioctyl sebacate results in greatly improved low-temperature flexibility without sacrifice of chemical resistance.

Second, the addition of a stabilizer is essential for maximum resistance to heat and ultraviolet light. Stabilizers such as Dyphos, Stabilizer A-5, Epon RN-34, Ferro No. 909, etc., when used to the extent of 5 percent based on the chlorinated rubber, add to the durability by retarding rusting underneath the coating.

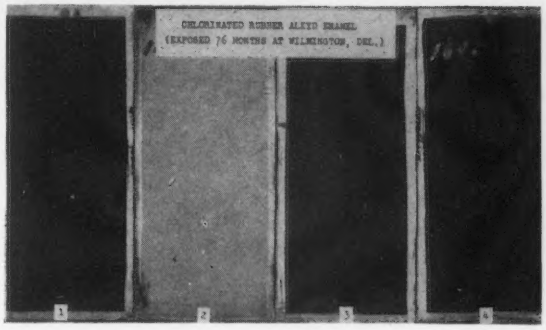



Figure 1

Instances have been reported wherein chlorinated rubber coatings have been outstanding with respect to their chemical resistance for a year or two but then failed prematurely when a rusting which developed under the film ultimately broke through. This has been overcome by many coatings manufacturers by proper primer formulation, especially by proper pigmentation. But where chlorinated rubber primers are used it is particularly important to incorporate stabilizer to prevent incipient rusting.

It should be understood that it is impossible to present formulations based on all the suitable resins and plasticizers used by the hundreds of coatings manufacturers who use chlorinated rubber, but the principles mentioned can be a useful guide in the preparation of specific chlorinated rubber coatings.

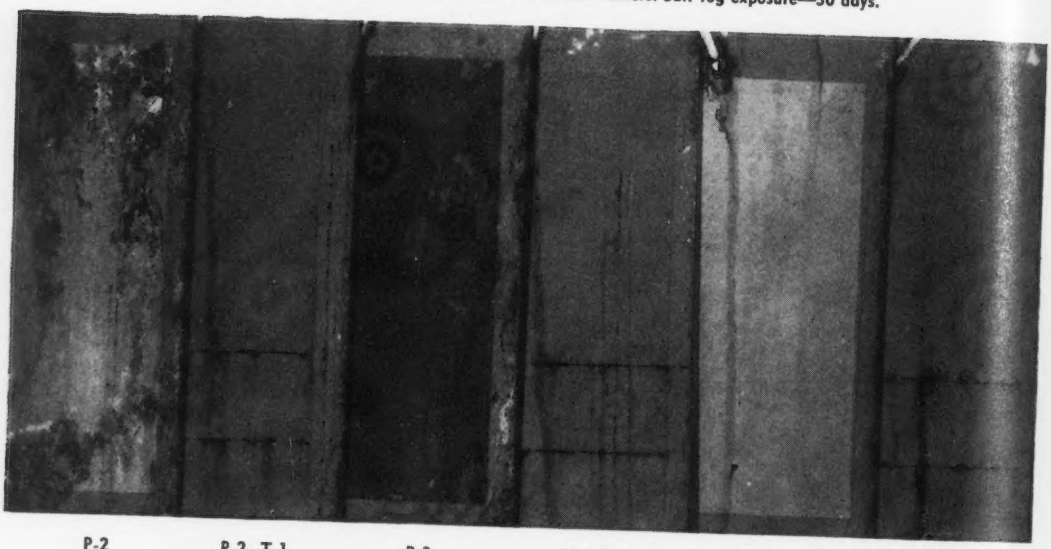
Chlorinated rubber is known to be one of the most practical of the film-forming materials which are resistant to acids, alkalies, salts, moisture and fungus growth. If principles of formulation are used which do not detract from the inherent resistance of chlorinated rubber, very satisfactory results are obtained.

Evaluation of corrosion-resistant finishes is best accomplished by exposing the coating to conditions occurring in actual use. Examples of this method are shown in the chlorinated rubber case histories presented later in this article. This method is very time-consuming, however, and numerous accelerated tests are available. Tide level exposure of corrosion-resistant coatings is one popular method of accelerating failure. The laboratory method covered by ASTM B-117-49T is equally as popular and more convenient to carry out. This procedure specifies that panels be exposed to a continuous spray or fog of 20 percent NaCl in a cabinet maintained at 95 degrees F. A water-immersion test in which panels are partially immersed in 100 degrees F tap water has been established as a useful complement to this test. Whereas the salt-spray test offers a good measure of the corrosion resistance of a system and an indication of its water resistance, the water-immersion test is regarded as a more severe test of water resistance. The evaluation, herein described, was based on these two tests.

Each finishing system examined comprised a primer and topcoat. Scored as well as unscored panels

T-1 | T-1, T-1 System 1 | P-1 | P-1, T-1 System 2

Figure 2—Effect of pigment in a chlorinated rubber vehicle. Salt fog exposure—30 days.



P-2 | P-2, T-1 System 3 | P-3 | P-3, T-1 System 4 | P-1 | P-1, T-1, System 2

Figure 3—Effect of vehicle in red lead primers. Salt fog exposure—30 days.

P-8 | P-8, T-1 System 5 | P-9 | P-9, T-1 System 6 | P-10 | P-10, T-1 System 7

Figure 4—Effects of chlorinated rubber topcoat over different primers.

of each system were exposed to both the salt-spray and water immersion tests. In addition, both scored and unscored panels coated with primer alone were exposed in the two tests. The coatings were applied by spray on cold-rolled steel panels which had been sanded to a uniform surface and solvent-washed.

Thirty-one finishing systems were evaluated. The panels exposed to salt spray were photographed after 30 and 60 days' exposure. Several of these photographs (Figures 2 to 8) clearly illustrate what is required of both primers and topcoats exposed to corrosive conditions and the role chlorinated rubber can play in such systems. Compositions of each paint film pictured in Figures 2 to 8 are given in Tables I, II and III. Data on the water-immersion resistance of these same systems are summarized in Table IV.

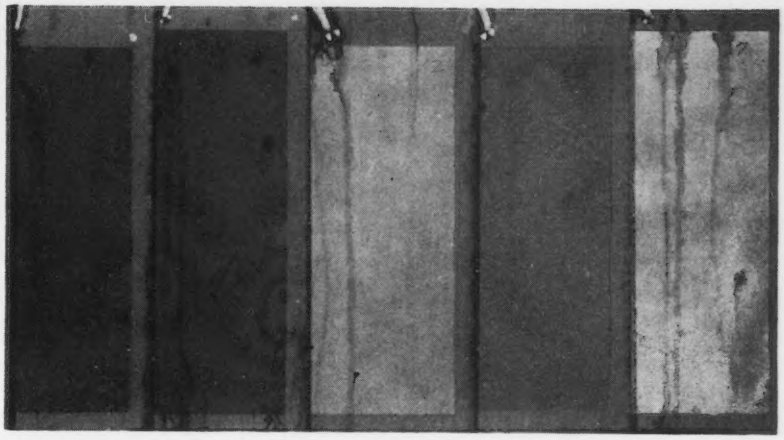
The composition of the topcoat (T-1) used in most of these tests was as given below in Table I.

This coating has an excellent performance record as a maintenance paint applied to structures and equipment which are exposed to corrosive conditions. Chlorinated rubber requires large proportions of aromatic solvents for complete solution. For this reason primer vehicles used in conjunction with it must be chosen carefully to avoid lifting of the primer by the topcoat. This restriction has limited the number of suitable primers for chlorinated rubber paints, establishing a definite need for a greater variety of more versatile primers. Fulfilling this need was one of the primary objectives of this work.

Primers are presumed to be necessary components of a finishing system to obtain either one or all of the following properties:

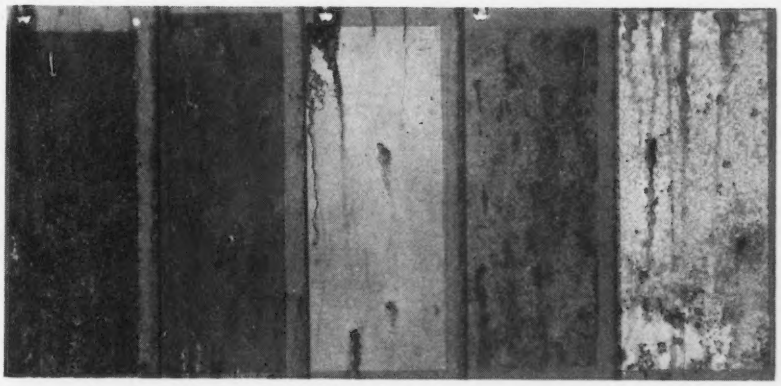
1) Build
2) Adhesion
3) Corrosion Resistance

The latter property would, of course, appear to be the most important for a salt-spray-resistant finish. Adhesion, in most cases, would be considered adequate if lack of it does not lead to loss of protection.



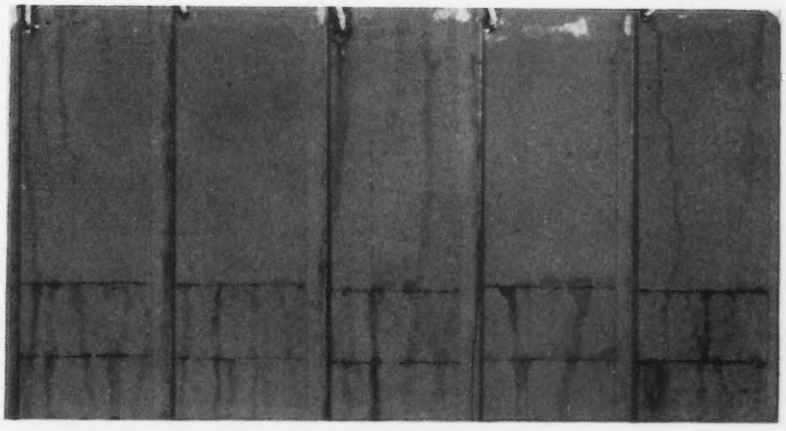
P-5 P-4 P-1 P-6, 7 P-7

**Figure 5—Comparison of several primers with no topcoats. Salt fog exposure—30 days.**



P-5 P-4 P-1 P-6, 7 P-7

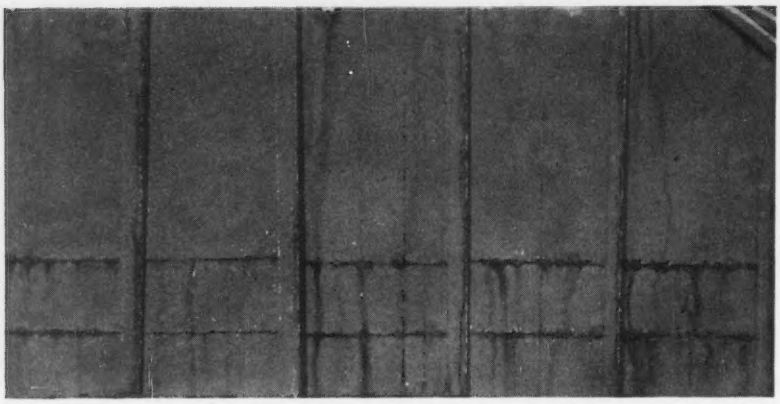
**Figure 6—Comparison of several primers with no topcoats. Salt fog exposure—60 days.**



P-5, T-1 System 8 | P-4, T-1 System 9 | P-1, T-1 System 2 | P-6, 7, T-1 System 10 | P-7, T-1 System 11

**Figure 7—Comparison of corrosion-resistant paint systems. Salt fog exposure—30 days.**

System 1, Figure 2 demonstrates that the use of a primer only as a means of obtaining build does not result in good salt-spray resistance. Here the chlorinated rubber topcoat, which is known to be itself resistant to corrosion and resistant to moisture, was used as its own primer. Although reasonably good metal protection was afforded as long as the film was continuous, severe undercutting or creep occurred at the scores. In System 2, Figure 2, the same topcoat was applied over a primer based on the topcoat



P-5, T-1 System 8 | P-4, T-1 System 9 | P-1, T-1 System 2 | P-7, T-1 System 11 | P-6, 7, T-1 System 10

**Figure 8—Comparison of corrosion-resistant paint systems. Salt fog exposure—60 days.**

vehicle, pigmented with red lead. Here the primer alone offered good protection while the film was unmarred, and creep at the score was greatly reduced in the complete system. These panels illustrate the advantage to be gained by the use of a corrosion-inhibitive pigment in the primer.

The common red lead-raw linseed oil primer incorporates the indicated corrosion-inhibitive pigment, and has, in fact, been widely used beneath a chlorinated rubber topcoat similar to T-1. This use is chiefly for maintenance applications where chemical resistance is desired. The major disadvantage of this primer is its slow drying rate, necessitating a lapse of 3-7 days between application of primer and chlorinated rubber topcoat. Systems 3 and 4, Figure 3, were primed with a standard red lead-oil and a fast-drying (alkyd-modified) red lead-oil primer, respectively. Severe erosion of these primers occurred when they were exposed without topcoats. The topcoated surfaces afford better protection, but the photographs do not show the lifting which occurred at the score. The systems containing the red lead-oil primers, therefore, were actually rated several degrees less efficient than System 2, containing the chlorinated rubber-red lead primer, again shown in Figure 3. These comparisons point to the fact that a salt-spray-resistant primer requires not only a corrosion-inhibitive pigment, but also a corrosion-resistant vehicle, assuming that any finishing system in normal service will ultimately suffer breaks in the topcoat.

**TABLE I**
**Topcoat Paint for Primer Evaluation**

| VEHICLE | Designation T-1 |
|---|---|
| Chlorinated Rubber, 20-cp. | 55 |
| Clorafin 42S | 30 |
| Aroclor 5460 | 15 |
| Stabilizer A-5 | 1 |
| **Pigmentation** | |
| Titanium Dioxide (R-610) | 98 |
| Lampblack | 2 |
| Pigment/Vehicle Solids Ratio | 33.3/66.7 |

**TABLE II—Primer Formulations**

| VEHICLE | DESIGNATION P-1 | P-2 | P-3 | P-4 | P-5 |
|---|---|---|---|---|---|
| Chlorinated Rubber, 20-cp. | 55 | .... | .... | 33.3 | .... |
| Rezyl 869 | .... | .... | 32.5 | 66.7 | .... |
| Rezyl 775 | .... | .... | .... | .... | 100 |
| Clorafin 42S | 30 | .... | .... | .... | .... |
| Aroclor 5460 | 15 | .... | .... | .... | .... |
| Raw Linseed Oil | .... | 100 | 67.5 | .... | .... |
| Stabilizer A-5 | 1 | .... | .... | 0.4 | .... |
| Aluminum Stearate | .... | .... | 1.17 | .... | .... |
| 6 Percent Cobalt Naphthenate | .... | 0.17 | 0.47 | 0.6 | .65 |
| 6 Percent Manganese Naphthenate | .... | 1.67 | 1.12 | .... | .... |
| 24 Percent Lead Naphthenate | .... | 4.13 | 2.81 | .... | 1.68 |
| **Pigmentation:** | | | | | |
| Zinc Oxide (Kadox 15) | .... | .... | .... | 15.9 | .... |
| Red Iron Oxide (Mapico No. 516 Dk.) | .... | .... | 25 | 14 | 29 |
| Zinc Chromate (du Pont Y539D) | .... | .... | .... | 10.8 | 52.5 |
| Magnesium Silicate (Asbestine 3X) | .... | .... | .... | 17.3 | 9.25 |
| Mica (Aratone 270) | .... | .... | .... | 42 | .... |
| Diatomaceous Silica (Celite 110) | .... | .... | .... | .... | 9.25 |
| Red Lead | 100 | 100 | 75 | .... | .... |
| Pigment/Vehicle Solids Ratio | 60/40 | 80/20 | 75/25 | 76/24 | 66.7/33.3 |

**TABLE III—Primer Formulations**

| VEHICLE | DESIGNATION P-6 | P-7 | P-8 | P-9 | P-10 |
|---|---|---|---|---|---|
| Vinylite VAGH | .... | 100 | .... | .... | .... |
| 25-Gal. Modified Rosin Ester Tung Oil (Varnish Solids) | .... | .... | 100 | 100 | 100 |
| 6 Percent Cobalt Naphthenate | .... | .... | .43 | .43 | .43 |
| 6 Percent Manganese Naphthenate | .... | .... | .43 | .43 | .43 |
| 24 Percent Lead Naphthenate | .... | .... | 1.09 | 1.09 | 1.09 |
| National Aniline A.S.A. | .... | .... | .017 | .017 | .017 |
| Polyvinyl Butyral Resin (Vinylite XYHL) | 7.16 | .... | .... | .... | .... |
| Basic Zinc Chromate (M-1828) | 6.84 | 60 | .... | .... | .... |
| Magnesium Silicate (Asbestine 3X) | 1.05 | 40 | 9.3 | 9.3 | 9.3 |
| Lampblack | 0.08 | .... | .... | .... | .... |
| 2B Ethanol | 48.55 | .... | .... | .... | .... |
| n-Butyl Alcohol | 15.93 | .... | .... | .... | .... |
| Zinc Chromate (du Pont Y539D) Soluble Type | .... | .... | .... | 9.3 | .... |
| Titanium Dioxide (R-110) | .... | .... | 23.3 | 23.3 | .... |
| Zinc Oxide (Kadox 15) | .... | .... | .... | 6.7 | .... |
| Red Iron Oxide (S-116) | .... | .... | .... | .... | 43.7 |
| China Clay | .... | .... | 9.3 | .... | 9.3 |
| Barytes No. 1 | .... | .... | 58.1 | 51.4 | 37.7 |
| **Diluent:** | | | | | |
| Phosphoric Acid, 85 Percent | 3.68 | .... | .... | .... | .... |
| Water | 3.29 | .... | .... | .... | .... |
| 2B Ethanol | 13.42 | .... | .... | .... | .... |
| Pigment/Vehicle Solids Ratio | .... | 52/48 | 80/20 | 80/20 | 80/20 |

**TABLE IV—Tap Water—Immersion Resistance**

| System | Primer | Topcoat | Primer Only | PRIMER—TOPCOAT Scored | Unscored |
|---|---|---|---|---|---|
| 1 | T-1 | T-1 | ..... | Very good | Very good |
| 2 | P-1 | T-1 | Very good | Very good | Very good |
| 3 | P-2 | T-1 | ..... | Poor | Fair |
| 4 | P-3 | T-1 | Poor | Poor | Fair |
| 5 | P-8 | T-1 | Poor | Poor | Poor |
| 6 | P-9 | T-1 | Fair | Good | Very good |
| 7 | P-10 | T-1 | Fair | Poor | Fair |
| 8 | P-5 | T-1 | Fair | Fair | Fair |
| 9 | P-4 | T-1 | Very good | Poor | Fair |
| 10 | P-6, 7 | T-1 | Very good | Poor | Fair |
| 11 | P-7 | T-1 | Poor | Good | Very good |

A common primer vehicle (25-gallon oil length phenolic-modified rosin ester — tung oil varnish) was used in Systems 5, 6 and 7, Figure 4. Primers P-8 and P-10 (Systems 5 and 7), respectively, were formulated to obtain build and improve adhesion with no regard for corrosion resistance. Primer P-9 represents a revision of P-8 wherein the pigmentation is altered to include 9.3 percent zinc yellow and 6.7 percent zinc oxide in place of equal quantities of China clay and barytes, respectively. Primers P-8 and P-10 failed completely without a topcoat while Systems 5 and 7 were subject to lifting and blistering both on scored and unscored surfaces. These photographs illustrate that adequate salt-spray resistance results only through the use of a primer which imparts not only build and adhesion, but also corrosion resistance to the film, thus confirming the need for a corrosion-inhibiting pigment.

In summation, Figures 2, 3 and 4 confirm that a primer is a necessary component of a corrosion-resistant finishing system and further serve to show that such primers should embrace a pigmentation capable of inhibiting corrosion, and a vehicle which is itself resistant to corrosion.

Systems 2, 9 and 10 had the best salt-spray resistance of the 31 systems studied. The primers of these systems were P-1, a chlorinated rubber-red lead, P-4, a chlorinated rubber-modified alkyd and P-6,7, a 2-coat polyvinyl butyral wash primer-vinyl chloride copolymer-zinc chromate, respectively. In Figures 5 and 6 these primers are compared after 30 and 60 days' exposure with P-5, a 100 percent alkyd primer and P-7, a vinyl chloride copolymer resin-zinc chromate primer. After 30 days, only the 100 percent alkyd primer had suffered appreciable failure, while P-1 was in the best condition (Figure 5). The results obtained with P-7 alone were not unexpected, however, in view of the type formula used. All of these primers with the exception of P-1, the chlorinated rubber-red lead primer, were considerably less effective after 60 days' exposure than after 30 days' (Figure 6 vs. Figure 5). The 2-coat primer, P-6,7, had suffered severe pinholing and some lifting after 60 days' exposure.

Figure 7 depicts the same primers of Figures 5 and 6 topcoated with a common topcoat, T-1, after 30 days' salt-spray exposure. Here, Systems 2, 9 and 10 have given equivalent good protection while Systems 8 and 11 were less efficient. The same systems are shown in Figure 8 after 60 days' exposure. The manner in which failure develops can be judged by comparing Figure 7 with Figure 8, the same systems after 60 days. Here, System 9, based on a chlorinated rubber-modified alkyd vehicle, was superior by reason of having suffered the least undercutting and no lifting. System 2 suffered no lifting, but undercutting was quite severe. The other systems all developed both lifting and creep.

Thirty-day water-immersion test results, Table IV, for these same coating systems established that only System 2, containing the chlorinated rubber-red lead primer had entirely satisfactory water resistance. Failure of the remaining systems was either by lifting (at the score) or blistering. Systems involving vinyl chloride-type resin primers were satisfactory on unscored panels, but severe lifting occurred at the score regardless of the topcoat applied over them.

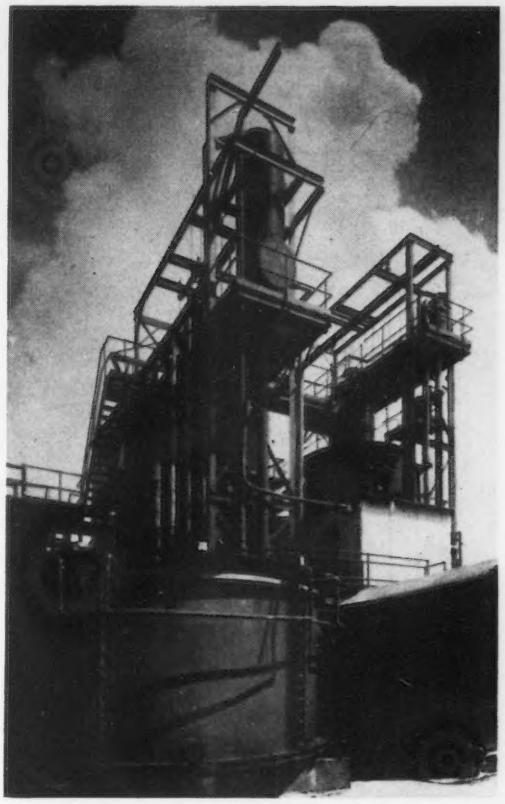


Figure 9

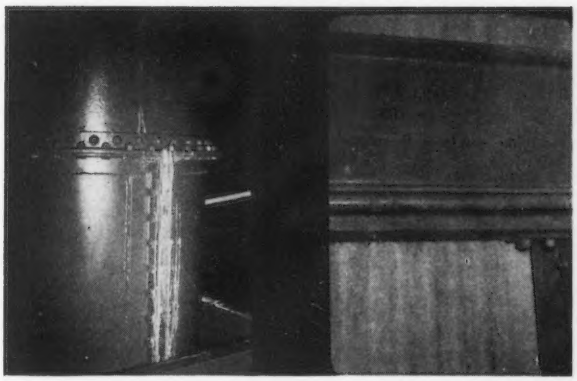


Figure 10

It is interesting to note that many of these coating systems exposed on unscored panels developed no failure after the 30 days' water-immersion test and likewise that many unscored panels have now been exposed to the salt-spray test for 150 days without failure.

As pointed out earlier, however, coatings in use generally suffer film breaks and for this reason emphasis has been placed on the results on scored

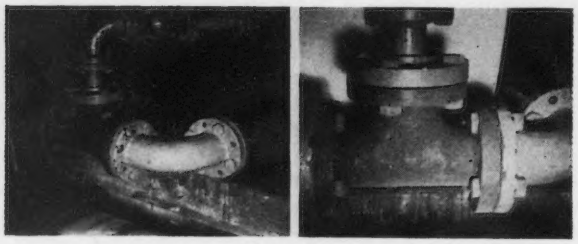


Figure 11

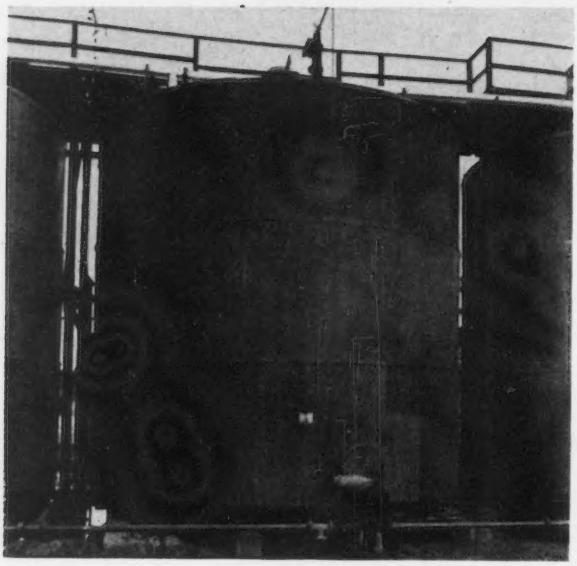


Figure 12—Acid storage tank after 3 years and 9 months' exposure with a chlorinated rubber coating.

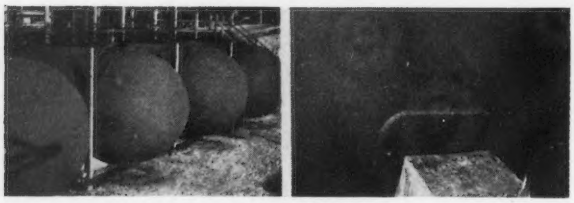


Figure 13

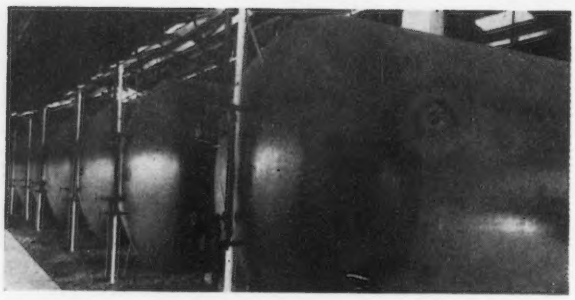


Figure 14—Ammonia storage tanks. Under cover exposure.

panels of complete systems and on the efficiency of primers exposed without topcoats.

Using the above criteria it can be concluded that topcoats based on chlorinated rubber vehicles have definite utility as salt-spray-resistant finishes. Furthermore, the excellent salt-spray resistance of

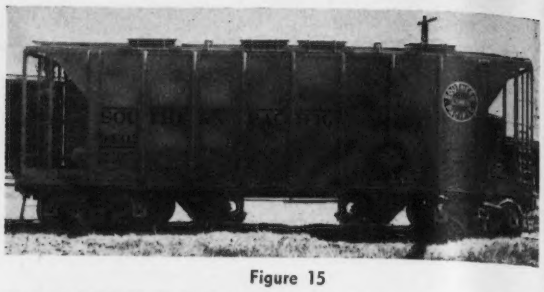


Figure 15

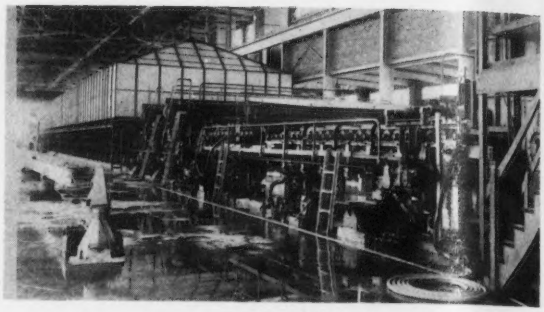


Figure 16

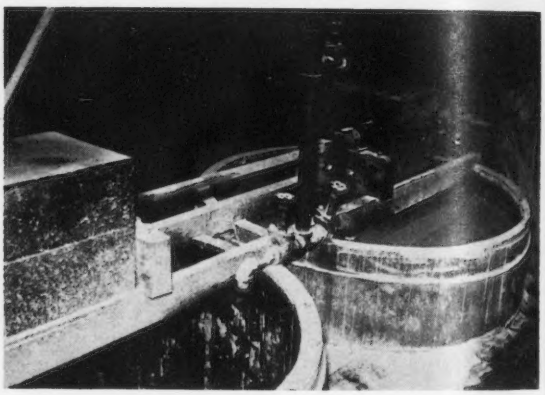


Figure 17

Systems 2 and 9 indicate a potential application for chlorinated rubber in corrosion-resistant primers.

One of the oldest continuous experiences with chlorinated rubber dates back 17 years when chlorinated rubber was used for the protection of a nitric acid plant shown in Figure 9. It happens that this plant, although protected with chlorinated rubber for the most part, has provided abundant opportunity to compare other types of coatings.

One of the most corrosive atmospheres of the plant is on the inside of the concentrator building. Nitric acid fumes there are usually of such concentration it is not comfortable in the building for very long periods—acid fumes are abundant and humidity is high.

Figure 10 shows the nitric acid concentrator after having been protected for four years with a chlorinated rubber coating. Most types of chlorinated rubber coatings gave outstanding protection during a four-year period.

Figure 11 shows a "T" on one of the lines of the nitric acid plant. The "T" itself was unpainted. After 1½ years it was very badly rusted and corroded,

whereas the adjacent connections to the "T," coated with chlorinated rubber, were still as attractive after 1½ years as the day they were coated.

Figure 12 illustrates another type of exposure. This is an acid tank coated with chlorinated rubber and shows the coated tank after 3 years and 9 months of exposure to outside weathering conditions in a plant area where acid fumes are particularly destructive.

Figure 13 shows ammonia tanks. In part of the photograph a closeup of the chlorinated rubber coating on one of these tanks after 3 years' exposure is shown.

Figure 14 shows similar ammonia tanks which are under cover. The corrosive conditions are especially serious under the cover of these tanks because of the high concentration of fumes which seem to "hand up" in the area.

It is of interest to note that the objects shown in Figures 9 through 14 were merely wire brushed prior to painting. The excellent durability of chlorinated rubber coatings applied under these conditions is quite advantageous since many coating systems require expensive sandblasting to obtain satisfactory durability.

Figure 15 shows a railroad hopper car. In this instance extensive tests on coatings for these hopper cars were made and chlorinated rubber coatings were selected because of the better durability which was demonstrated on cars used for the transportation of cement, soda ash and bulk chemicals. This photograph was taken after 14 months' exposure during which time the hopper car was in service. As the photograph indicates, the coating is intact and is still giving good protection. Some cars similar to this one have been used in transporting chemicals in the Western desert area. This service itself is quite rigid without the corrosive effects of the bulk chemicals which are transported.

The protection of paper mill equipment is an industrial application of chlorinated rubber coatings which began a dozen years ago.

Figure 16 shows a paper mill which has been coated with chlorinated rubber and in which years of experience have indicated its merit.

Figure 17 shows the alum tanks of another paper mill which had been coated with chlorinated rubber five years before. Papermakers' alum is an acidic material and a 5-year history with chlorinated rubber was recognized as quite an achievement.

Figure 18 shows steel work in a sulfate mill. This photograph was taken after a year's exposure at which time the merit of chlorinated rubber coatings had been established in this application.

Figure 19 shows a filter press in a mineral plant operation. This type of case history is included merely to illustrate the variety of equipment to which chlorinated rubber has been applied.

Figure 20 shows the application of chlorinated rubber to soft-drink equipment. The hardness, mar resistance and durability of chlorinated rubber coatings makes them outstanding for machinery of this kind. A most interesting case history in another plant of this general type was reported with respect to a

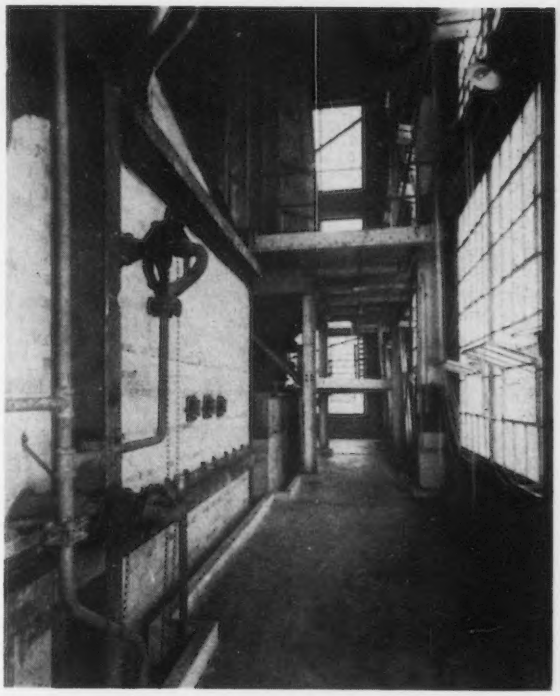


Figure 18

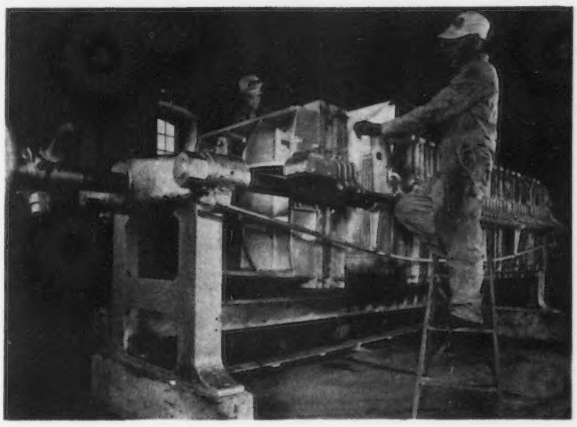


Figure 19

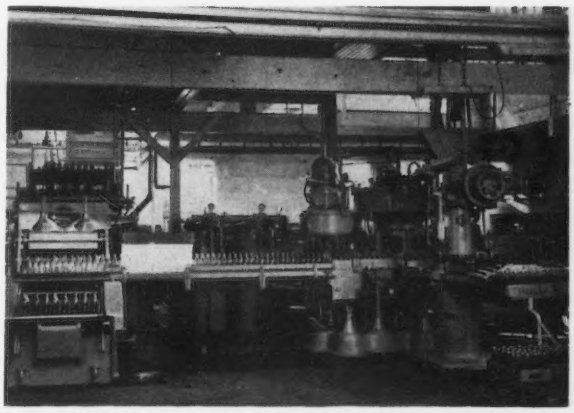


Figure 20

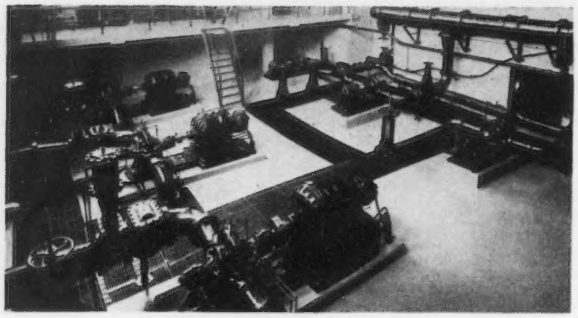


Figure 21

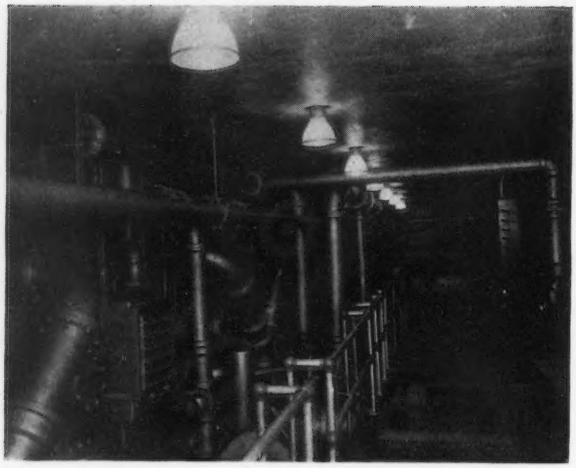


Figure 22

conveyor used for alkali bottle washing. Chlorinated rubber was applied to the conveyor for six months at which time the superior durability of chlorinated rubber had been established.

Figure 21 shows the attractive condition of electric motors, water pumps, steel grill work and pipes which have been coated with chlorinated rubber.

Possibly one of the most romantic experiences ever recorded about chlorinated rubber coatings on electric motors came as a result of the investigation of the sunken submarine "Squalus." After being at the bottom of the ocean for several years the "Squalus" was finally raised. After removing the mud and mire from electric motors which had been coated with chlorinated rubber coatings, it was found that the coating was still on the motor and protecting it in a remarkable fashion.

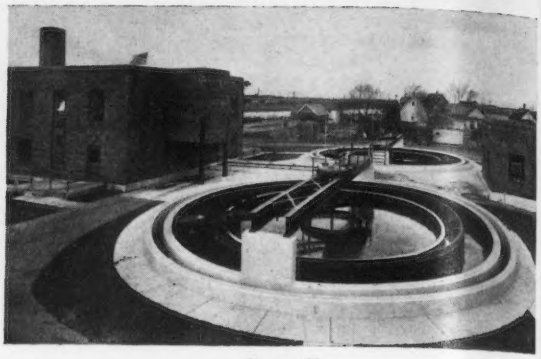


Figure 23

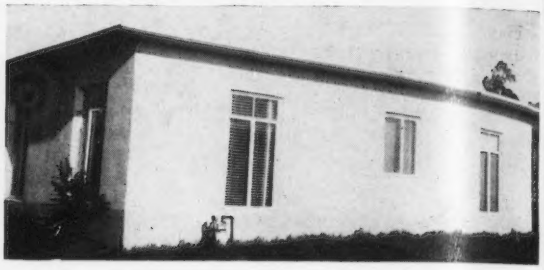


Figure 24

Figure 22 shows pipes in a water plant. Chlorinated rubber is outstanding in this instance because of its high degree of resistance to water and humidity, which is supported by much published technical information on the subject.

Figure 23 shows one of many of the sewage disposal plants in which the performance of chlorinated rubber has been outstanding because of its corrosion resistance.

A brief review of other types of applications in which chlorinated rubber has been exposed to alkaline conditions appear to be of interest.

Figure 24 shows a stucco house. This was coated with chlorinated rubber several years ago and was recently inspected. On the southern side, which is shown in the photograph, there was more exposure to sunlight than on the other sides. The chlorinated

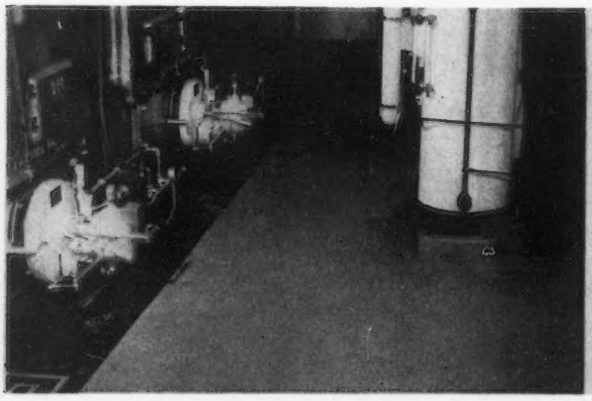


Figure 25

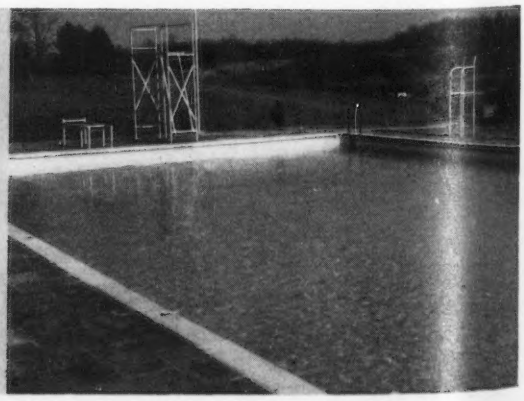


Figure 26

rubber coating on the southern side had faded slightly and and lost a good deal of its gloss, but was otherwise in excellent condition.

Figure 25 shows the basement of an industrial institution after more than a year's exposure. There was no sign of deterioration in the chlorinated rubber film.

Figure 26 illustrates the effectiveness of chlorinated rubber submerged in water and under conditions which frequently mean a breakdown of coatings by the alkalinity of concrete. Swimimng pools coated for several years with a chlorinated rubber coating may be found in all parts of the country.

In summary, chlorinated rubber is a material which should be considered among the best of chemical and corrosion-resistant coatings.

## DISCUSSION

**Question by A. J. Liebman, Dravo Corp., Pittsburgh, Pa.:**

Reference is made to blister formations under chlorinated rubber coatings when the coatings are applied to structural steel or over old paints. Is the coating sufficiently porous to permit moisture permeation through the coating in the event slight moisture deposits are trapped under scale or on rusted structure members? Does the coating form good adhesion to all old paints?

**Author's Reply:**

In answer to the first question relative to the moisture permeation of chlorinated rubber coatings, it may be stated that chlorinated rubber coatings are among those most resistant to the passage of moisture. This fact has been confirmed in tap water immersion tests (100° F), where Parlon coatings resisted the penetration of moisture for over 45 days. Alkyd resins and linseed oil coatings failed in a few days under this test.

Chlorinated rubber coatings have been applied to pre-rusted (dry) panels to evaluate the protection offered without thorough surface preparation. Salt fog exposure of such panels demonstrated the effectiveness of chlorinated rubber coatings on this type of substrate. The protection was far greater than that offered by alkyd-based paints.

Moisture permeability is, of course, a function of both binder and pigment. Most relatively water-insensitive pigments effect a slight decrease in permeability up to approximately 40 per cent pigment volume. Beyond this point (often called the "critical pigment volume"), a sharp increase in permeability occurs as pigment volume is increased. In this respect moisture permeability of coatings is a function of pigmentation and it often can be controlled (within limits) by formulation. In general, however, it can be stated that chlorinated rubber vehicles are less permeable to moisture than oil-based vehicles. Wherever greater permeability is required, it can be achieved by higher pigmentation.

Insofar as we have been able to determine, chlorinated rubber offers good adhesion to old paint films of all types. The surface must necessarily be free of all grease or wax for the best adhesion.

**Comment by William F. Connors, Humble Oil and Refining Co., Houston:**

We have experimented with chlorinated rubber coatings for the past 10 years. Their use on special interior applications has given excellent results. On exterior exposures, areas exposed to sunlight or ultraviolet rays, we have experienced checking. These checks are somewhat similar to those experienced on garden hose when left out in the sunlight, or on other rubber type products. The checks finally result in cracks.

Is this due to faulty formulation on our part or does this type coating have the same type characteristics as other rubber type products?

**Author's Reply:**

In answer to this question we might say that our experience with chlorinated rubber has shown that proper formulation and stabilization should overcome any checking problem on the outdoor exposure of pigmented coatings.

A vehicle having the following composition has shown excellent resistance to checking on outdoor exposure:

| | |
|---|---|
| Parlon, 20-cp. | 55 |
| Aroclor 5460 | 15 |
| Aroclor 1254 | 24 |
| dioctyl sebacate | 6 |
| Dyphos | 2.75 |

A replaceemnt of 20 percent of the primary plasticizer, Aroclor 1254, with dioctyl sebacate results in a film that sacrifices little in chemical resistance and gains in increased resistance to checking.

Sunlight or ultraviolet light has a considerable effect on the breakdown of clear Parlon films; however, pigmented films are quite stable. The addition of stabilizers to the Parlon films is also advantageous in preventing ultraviolet breakdown. The stabilizers showing the most promise are Dyphos (National Lead), CS-137 (National Lead Co.), and Witco No. 70 (Witco Chemical Co.). The most efficient level of stabilization is 5 per cent based on the chlorinated rubber content.

The addition of a bodying agent such as Bentone 34 (an amine of anhydrous aluminum silicate, National Lead Co.) also is claimed to increase the resistance to checking because of the expanded gel lattice it imparts to the film. Excellent results were obtained with 2 percent by weight of Bentone 34 based on the total paint.

Pigment volume concentration also plays a large part in the prevention of checking in Parlon films. Within limits, films of low pigment volume show greater tendency to check the optimum resistance being in the vicinity of 30 to 40 percent.

# Radiant Heating Systems Need Cathodic Protection Too*

By J. F. HIRSHFELD* and L. P. SCHAEFER**

**Abstract**

For approximately $30,000 two cathodic protection systems were installed in two bus garages of the Detroit City Department of Street Railways avoiding replacement of a radiant heating system installed under garage floors with a less efficient space heater arrangement which would have cost $80,000. The radiant heating system piping, installed in a sand fill beneath a concrete floor in soil of high corrosivity provided heat for about 500,000 square feet of floor space. Salt and water melted from buses stored in the garages, seeped through cracks in the concrete floor causing between 150 and 200 leaks under one building alone and the loss of about 3000 gallons of 140 degree water per month. The cathodic protection system consisted of graphite anode rods installed under the concrete floor connected to selenium rectifiers of appropriate capacity. Accurate check of potentials is being kept.

A SERIOUS CORROSION problem which was encountered very early in the newly constructed storage and maintenance garages of the Department of Street Railways, City of Detroit, was solved by installing a graphite anode cathodic protection system. Leaks in the piping, caused by corrosion, kept the radiant heating system from operating efficiently with a minimum of down time and maintenance. An explanation of the problem will make this clear.

Detroit is a city of bus transportation. Hundreds of buses are needed to serve one and three-quarter million people and extensive facilities are required to store, service and maintain them. Four years ago the Department of Street Railways took a long step toward better, faster and more efficient bus service by building three new terminal garages as the initial step in a carefully integrated transportation plan. Each building contains 250,000 sq. ft. of floor space, is extremely modern in functional design and architecture. Each one also serves the two-fold purpose of providing storage space as well as service and maintenance, with every facility needed to keep the buses in first class condition for running efficiency and passenger comfort. Each building can store between 450 and 500 buses.

When a bus is run into a garage for storage, repairs or regular maintenance and servicing during the winter months the very first operation is to melt the accumulation of snow, ice and slush from its underside. Detroit winters are cold, the season is long and there is plenty of snow and ice to harass the men whose duty it is to keep transportation running and on schedule. A bus may pick up as much as a ton of filthy snow and ice during one "trick." The mixture is thoroughly saturated with salt which is used by the city on its streets for snow and ice removal — a practice also found in many other cities.

To melt this accumulation of frozen material and to provide ideal working conditions for employees a radiant heating system was placed under the floor of each garage. The pipes, in the form of radiator-like units, are laid in a sand fill immediately under the concrete. Each unit or panel is fed from a manifold system and drained to a similar manifold. In and out valves make it possible to by-pass any panel without interfering with the operation of the rest of the system. A main manifold is strung along each length-wise wall in the floor sand fill with seven "risers" leading to the heating panels. A valve at each riser permits drainage of the entire system.

While the primary function of the radiant heat in the floors is to throw heat to the underside of the buses, the heating of the buildings is an important auxiliary purpose. A storage garage temperature of between 40 and 45 degrees F is maintained by circulating thousands of gallons of 140 degree water per hour, while the service portions of the buildings are maintained at 60 to 70 degrees F.

Naturally, one of the very important operating objectives is to keep the heating system operating efficiently and with a minimum of down time and maintenance. Any difficulty that interferes with the constant and full capacity operation of the system is critical because the city-wide schedule of bus operation is keyed to the maintenance and servicing routine, which, in turn, is dependent upon the heating cycle once the bus is in the garage and out of service.

The brine water product of the melted ice and snow leaks through the slab joints and other cracks in the floor and eventually seeps through the concrete itself into the sand fill directly under the floor to aggravate a corrosive condition already existing because of the nature of the soil itself. The garages are built on old industrial sites which had been filled with non-descript

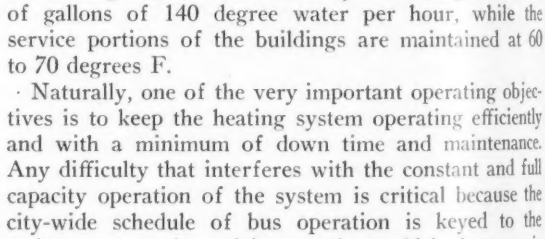


**Figure 1—St. Gilbert Bus Terminal, Department of Street Railways, City of Detroit, Mich.**

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fill dirt, cinders, bricks and the inevitable mixture of salt. By the end of the second heating season deterioration from corrosion of the radiant heating panels was so severe that it was necessary to abondon the radiant heating system in one of the bus terminals and leaks were developing at an alarming frequency at the other two terminals. That such a condition developed in spite of the advanced engineering practices employed illustrates the need for a greater realization of the extent of corrosion of buried metal structures and the knowledge of its mitigation by cathodic protection. In an effort to salvage the radiant heating systems, The Hinchman Corporation was asked to make a survey of the leakage and to determine whether cathodic protection could be used to prevent further deterioration of the heating system. The preliminary survey determined that cathodic protection was practicable, and as a result, cathodic protection systems were designed for the S. T. Gilbert and Coolidge Terminals.

A leakage survey showed between 150 and 200 leaks at the Coolidge building and leakage at the Gilbert garage amounted to about 3000 gallons of water per month. The magnitude of the repair work became apparent at once. Locating the leaks, ripping up the concrete floor to get to them, making the repairs to the pipe and then replacing the floor was an expensive procedure. A seven man leakage repair crew worked from last September into the present year.

The radiant heating pipes in those two buildings add up to a surprising total of approximately twenty-one miles of 1½ inch steel and wrought iron pipe arranged in 133 panels in the Coolidge building and 100 panels in the Gilbert, to provide a heating surface of 30,000 sq. ft. for Coolidge and 25,000 for Gilbert.

The soil potential tests showed a strong corrosive condition and a graphite ground anode cathodic protection system was calculated and engineered. Fortunately no interference with other structures was found, although as a protective measure, all underground lines within the garages were electrically bonded. These included oil lines and the supply lines for the sprinkler system. The radiant heating supply pipes at the ceiling were already bonded to the building structure so that column footings were protected. Additional precautions are being taken to guard against any leakage or stray currents from the protection system.

Pavement covers the entire area in and around the storage garages so that permanence and continued efficient operation of the ground beds were important factors in the design of the cathodic protection system. For these reasons as well as for economy, graphite rods were selected as the logical material for the ground beds.

There were two possible arrangements for a ground bed. The easiest was to place graphite ground rods at proper intervals around the outside of each building close to the foundation. However, a number of construction conditions and the pattern of the soil resistivity, which varied from 600 to 3000 ohms per cu. cm. ruled out this method.

The ground rods subsequently were put right under the floor of the garages. This was a difficult task because of working limitations. Thirty-four groups of 4-inch by 40-inch graphite ground anodes were placed

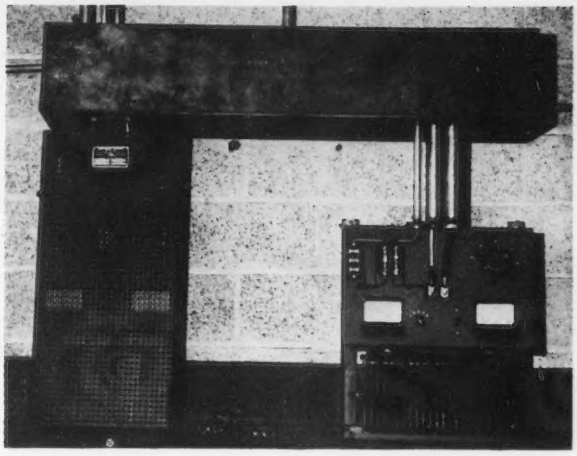

**Figure 2—Control box and air-cooled selenium rectifier used in system.**

under each of the two buildings; each group consisting of two rods, placed under heating panels. Because of the arrangement of the panels the spacing between each anode group varied from about 57 ft. to 102 ft. and as a result every panel did not have ground rods under it, although a practical approach to symmetry was achieved. The anode holes were bored with a power auger to a depth of 8 feet and a diameter of 24 inches. This diameter was required to allow room for the backfill material around the two rods placed together in the center of the hole to form one "group." The depth was limited by the head room in the garages for getting the auger in and out of the holes, and for this reason the two 40-inch anodes were placed in each hole rather than a single 80-inch anode. A total of 68 anodes thus were installed in each garage, with a coke breeze backfill. The anodes are deep enough to allow two feet of coke breeze to cover them, plus a layer of sand just under the floor. The holes in the concrete floor were filled and sealed with black mastic. This was felt to be practical from the standpoint of servicing or checking the rods. The anode leads are enclosed in pipe conduit and are spliced to a conduit enclosed distribution bus of 3/0 copper conductor. The distribution feeder is connected to air cooled selenium rectifiers mounted on the wall, and the distribution system has a one volt drop between the rectifier and the most remote anode at a distance of some 470 feet away.

The Gilbert ground bed is fed by one 40-ampere, 12-volt rectifier, and one 60-ampere, 12-volt unit, both mounted in the storage part of the building. The Coolidge system is energized by two 60-ampere, 12-volt rectifiers arranged similar to the Gilbert set up and mounted in the service garage.

Another unique and economical feature of this installation is the fact that the rectifiers are inside the buildings and thus are protected against the effects of outside exposure.

After the system went into operation additional leaks in the piping, which were not unexpected, occurred almost immediately. This was because a heavy oxide coating encased the pipe to a thickness of about ¼-inch. As this oxide coating was dissipated by the current flow existing leaks sealed by the coating opened up. These

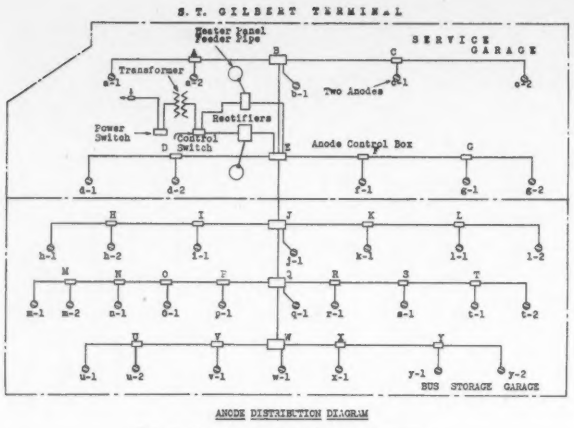


**Figure 3—Anode distribution diagram.**

leaks are not numerous enough to be of consequence and will be repaired at opportune times as a part of maintenance schedules.

Pipe-to-soil potential tests were taken immediately and are being checked at frequent intervals. Complete operation and maintenance manuals of each cathodic protection system have been furnished DSR Operating Personnel to assure proper continued functioning of the protective installation. As a result of this a continuous log record is being kept to give a constant comparative condition report. Potential measurements are taken between the shutoff valves and the concrete for those heater panels which are most remote from the anodes. A copper-sulfate half-cell is used and the exact location on the concrete floor has been marked with painted circles so that subsequent tests will duplicate all conditions as closely as possible. The half-cell placed on the wet concrete floor offers a good contact, although the test results which could be obtained with a "plumbers' helper" type of half-cell might be more repeatable and consequently this type will be substituted on some future tests.

Before the heater panels were energized the measured potential between the pipe and concrete as measured to a copper-sulfate half-cell varied between —0.4 and —0.7 volt. After the cathodic protection system had been in operation for 30 days but before anode currents were readjusted, the potential had dropped to between —0.75 and —1.2 volt, representing a relative voltage change of from 0.15 to 0.50 volts. It was estimated that the heavy oxide coating would not be completely loosened and the protective system stabilized for a period of eight months to a year after the system was placed in operation.

All of the construction and installation work was done by the electrical crew of the DSR under the supervision of The Hinchman Corporation engineers. Installation work was completed and the system placed in operation in one month.

The complete cathodic protection system for the two garages cost approximately $15,000 each, in contrast to $80,000 which would have been spent to replace the radiant heating system with space heaters and which would have resulted in a less efficient heating job for these large terminal types of buildings.

There is every reason to believe that many bus and truck operating companies with similar operating problems might profit from the experience of the Detroit Department of Street Railways. This is especially true of those companies thinking about modernizing or expanding present facilities. It is much cheaper to include a cathodic protection system in new construction, thus avoiding corrosion damage and the higher cost of subsequent installation.


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(Quoted from "Guide for the Preparation and Presentation of Papers." National Association of Corrosion Engineers, 919 Milam Bldg., Houston 2, Texas.)

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# Physical Chemical Aspects of Corrosion Inhibition*

By NORMAN HACKERMAN*


## Abstract

Some of the basic physical and chemical phenomena which can occur during the inhibition of the corrosion of metals by liquid environments are discussed. The way in which each of these may be involved and their relative importance in the overall process is considered. Several recent researches in this field are examined to point up the variety of physical chemical approaches used.


## Introduction

THE VARIOUS approaches to the problems of metal corrosion are almost equal in number to the several divisions of science and technology. In the final step in the practice of corrosion prevention it is the engineering outlook which must predominate. This step usually requires experience with the specific problem or experimentation of an applied nature. Such experiments are performed in the functioning system itself or in a test in which the conditions of the actual operation are reproduced as faithfully as possible.

One step removed from such inquiries are those studies in which some variables are eliminated from the system in order to learn more about the influence of other tangible controlling conditions, for example, determination of the effect of temperature at constant flow rate. Testing of this sort may be used as a basis in predicting the effects which might be expected in practice when operating conditions change.

At the base of all experimentation which falls within the first two categories is the type of fundamental information which is obtained from that which is often termed 'pure' research. Such information comes most often from researches which stem wholly from the inquisitiveness of the worker. Sometimes, however, studies of this kind are arranged by those who seek basic information with the thought in mind of eventual application in the solution of practical problems. In either event, the experimental system is arranged so that all known independent variables are carefully controlled and one or more properties or change in properties is measured. The metallurgist, the physicist, or the chemist engaged in this kind of research is concerned with first principles, which may be far removed from the practical answer required by the engineer in the field. Nevertheless, in time, the information gained and the theories based on it become useful to the engineer.

### *Scope of the Field of Corrosion Inhibition*

The basis of researches into corrosion inhibition is the means by which materials added to the fluid environment retard the reaction between it and the metal. One large segment of the field concerns the effect of the additive on the corrosivity of the environment. This area of study is arbitrarily eliminated here and so follows the equally arbitrary common usage of the term 'corrosion inhibitor.' The discussion is also restricted largely to liquid environments. Therefore, there remains the effect on the reactivity of the metal of adding chemicals to the solution.

The processes of inhibition are not only not uniform with respect to all inhibitors or types of inhibitors but are not even constant and consistent with one inhibitor in a given system. That is, a specific material may be required to perform more than one function in order to be reasonably effective. Generally, it has been desired that a single compound be capable of doing this alone, but it now is clear that in many instances combinations of chemicals are more likely to provide the multiple services needed.

The general ways in which a corrosion inhibitor may function are twofold:

a) by reaction with the metal ion newly produced in the environment but in a plane very near or on the metal surface;

b) by adherence to the metal surface through the metal ion still in place in the lattice (i.e., by adsorption).

The reaction rate is altered either by change in rate of access of the reactants to one another (diffusion control) or by decrease in activity of the metal. The latter is a more fundamental change which includes electrochemical influences. Either or both of these factors must be described in rate equations which undertake to describe the systemic variables quantitatively.

## Experimental

### *General Fields of Applicable Interest*

The fields of interest, aside from the kinetics of heterogeneous reactions involving electronic conductors, consist of those which have to do with the components of the corrosion system. This embraces a wide segment of scientific endeavor because the components are solids, solutions and interfaces. Thus, it is useful to know something of: the physics of the solid state, especially as it pertains to the properties

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*Department of Chemistry, University of Texas, Austin.

of metals and of solid reaction products; of solution chemistry in terms of interactions between dissolved metal ions and solution components (as in complex ion formation) and in terms of the particular species which is the effective inhibitor particle; and of interfacial phenomena with respect to adsorption of the surface-active species and its influence on wetting properties, on the physical nature of precipitated corrosion products and on the intrinsic properties of the metal.

Kinetic studies are the most directly applicable, and all practical investigations are designed to provide over-all rate data. In basic laboratory studies the principal objective is more often the determination of the reaction mechanism and energetics. Frequently, useful information for this purpose stems from determination of temperature coefficients. This makes it possible to decide whether a rate is controlled by diffusion or by one or more chemical reactions. Temperature effects alone usually cannot provide sufficient information to choose a single change within either of these groups as the rate determining step. However, it is possible to set up equations containing rate constants for all of the steps which might be visualized. By a systematic series of experiments designed to allow each step to function as the rate controlling segment alone, it becomes more nearly possible to decide on a mechanism. This is exemplified by the work of King and co-workers[1] and of Hurst and Jermyn.[2] Generally it is not possible to arrange experiments in such a clean-cut fashion and the conclusions reached are less firm. The best proof of the conclusion is, of course, accurate prediction and, next to that, satisfactory explanation of most of the known facts.

**Solids.** In most of these reactions, diffusion is the phenomenon of greatest import. So fundamental knowledge of diffusion through solutions, through membranes and through solids is necessary to analyze corrosion reactions in a manner analogous to that indicated above. Rates of precipitation and growth of precipitated particles are necessarily integral parts of these studies. This is so because particle size determines the mode of packing and, therefore, can be determining in rates of diffusion both of the reacting species and of the inhibiting species. Furthermore, the rate of precipitation may influence the movement of ions within the solid scale which forms on the metal. Evidence to support this contention is sparse, but intuitively it might be supposed that very rapid precipitation would lead to less perfect lattices and, therefore, to greater possibilities for reasonably rapid diffusion through the solid, even to the point where it might be a rate determining step for metal-solution reactions. On the other hand, rapid precipitation should lead to fine-grained, close-packed solids which would be likely to be retarding if diffusion *from* the solution to the metal was controlling, or if the more numerous crystallite boundaries impeded diffusion *to* the solution from the metal.

Even aside from the foregoing, it is clear that the nature of the solid corrosion products influences the course of reaction and, therefore, is a consideration in inhibitor studies. Basic researches into the relationship, if any, between rate of precipitation and lattice imperfections would be very useful. This, added to morphological studies (form and structure) of the corrosion product films and surface layers, should provide a base for hypothesizing the course of the reaction. Feitknecht's work[3] typifies this sort of study. Chemical microscopy, diffraction of high-frequency radiation and the use of radiotracers are applicable techniques in such studies.

The metallic state falls largely in the realm of the physicist who, in recent years, has made considerable progress in this field. Of particular interest in corrosion research are the intrinsic reactivity of the metal and the potential it acquires at its interface in a given medium. Direct rate measurement, as by weight change or solution analysis, does not provide information on inherent metal reactivity, except perhaps for the most reactive materials such as the alkalis. Steady state galvanic potential measurements and more recently corrosion current measurements have been used to show that standard electrode potentials alone are not suitable criteria of the reactivity of a metal in a dynamic sense. However, results of studies of the first two kinds are amenable to quantitative treatment and so the influence of additives on these properties may likewise be evaluated quantitatively.

Another type of measurement which holds some promise is that of the so-called contact potential of the metal relative to that of some reproducible standard metal surface, e.g., platinum. This difference, which can be measured directly, is related in a simple manner to the electronic work function of the metal. This is a measure of the energy necessary to remove the most easily removed electron, barring those in the conduction band. It is possible to determine the effect on contact potential of exposure of the metal to inhibitors and thus determine the influence of such materials on this very basic property.

Theoretical considerations make it possible to consider local electrodes as sites at which orbital electrons lie in high-energy levels from which they can be transferred readily either to the conduction band or across the interface to an acceptor particle in the solution. The former corresponds to an anodic site, and the latter to a cathodic site. The electrodes can be polarized from the metal side by imposition of an applied potential, or from the solution side by a passivator (as the term is used by Uhlig.[4]) In either case the effect is to drop the electron into a lower lying energy level, in the latter case by formation of a strong bond with the chemisorbed particle.

Alternatively, the surface of a solid can be considered to contain an excess of lattice defects (vacancies) over that in the bulk of the solid. Inhibitors might be sorbed most readily at these vacancies, because of molecular deformation in the strong asymetric fields, thereby reducing the tendency for ions to diffuse either into or out of the lattice, as the case may be. Admittedly, this is speculative, but it is

not unreasonable and it serves to illustrate the role of pure research in this field in corrosion problems.

**Solution Chemistry.** This field of study is pertinent in that corrosion may be considered fundamentally as the transfer of a metallic ion from one type of organization in the lattice to another type of organization in the solution. The metal lattice consists of ions arranged more or less symmetrically in space, each held to its neighbors by strong bonds, whereas in solution each metal ion is associated rather closely with solvent molecules and frequently with anions also. The extent of solvation and of complexing of the cations in solution is influential in determining the extent to which a corrosion reaction can take place according to thermodynamics. Inhibitors may disturb this state of affairs by preventing or reducing complex formation, or by accumulating the metal ions themselves, as in precipitation.

The chemistry of solutions applies also insofar as it provides an accurate knowledge of the way in which the solute actually exists in solution. This is particularly pertinent with organic inhibitors because such materials show a marked tendency to congregate in some way. Typical of this phenomenon is the association of aliphatic acids in benzene.[5] It was shown that the acids dimerize, associating through the carboxyl groups and that the extent of dimerization increases with increasing molecular weight. The importance of this fact is that the species usually adsorbed from a solution is the monomer and, therefore, the concentration of surface active particles does not necessarily increase when the weight percentage or molar concentration increases.

In this laboratory, evidence has accumulated which shows that the monomeric forms of certain alkyl substituted thioureas are actually corrosion accelerators. When a solution of the monomer is exposed to visible light, it polymerizes and in this form is capable of retarding the same reaction somewhat. The age-polymerized solid compound, which contains a mixture of monomers and polymers of various degrees, acts very effectively to retard corrosion.

Investigations into complexing, association and polymerization make use of a variety of experimental methods. Ultra-violet and visible spectrophotometry are principal tools for the first, infrared spectrometry as well as dipole moment measurements are used for the second and diffusion, x-ray scattering, and precise molecular weight determinations are among the methods used for the last.

**Interfacial Phenomena.** Since many inhibitors appear to function by virtue of adsorption on the metal, studies of the extent and nature of the uptake are basic to an understanding of the process. By making the area of solid surface large relative to the weight of metal used, it is possible to determine the actual weight increase on a given area of metal surface brought about by exposing the metal to solutions of the inhibitor. This requires that there be no interaction between the metal and any other component of the solution, e.g., the solvent, and that no solute be left on the solid simply by evaporation. The sample weights are usually large and the weight increases because of absorption are quite small, but with care it is possible to make the measurements.[6]

Change in solution concentration on contact with the metal can also be used, provided a sufficiently sensitive analytical method is available. Very precise determinations can be made using an interferometer, or by measuring the change in surface tension of the solution. In general, it is necessary to use a small enough volume of solution so that a sensible change in concentration is produced. A very effective means, which is now available, makes use of inhibitor particles tagged with a radioisotope. For example, compounds can be prepared using $C^{14}$, $P^{31}$, $As^{73}$, $Cr^{51}$ among others.

Sorption can be somewhat naively classified as either physical adsorption or chemisorption. In the former, the operating forces are weaker, of the type involved in condensation processes, while in the latter, the forces holding the adsorbed particle are more nearly like true chemical bonds. Insofar as corrosion inhibition is concerned, there are two important differences between the two, namely, the greater irreversibility of chemisorbed material and the more deep-seated changes which the metal surface undergoes when it receives chemisorbed material.

Probably the best means of distinguishing between the two is by testing for reversibility, for example, by washing metal with adsorbed material on it with solvent of the solution to which it was exposed, or by attempting to replace the adsorbed material with another substance. In gas-metal systems these procedures correspond to evacuation by pumping and to flushing with a gas not previously in the system.

Some effort has been expended in detecting adsorption and its type, by measuring changes in some characteristic physical property. In the case of metals, changes in galvanic potential have been used. The extent of change of steady-state potential and the ease of reversing the effect have been used to indicate what may be happening at the metal surface. There is a difference of opinion, however, in interpretation of the effects. One school of thought holds to the idea that this procedure provides a measure of film resistance, while another is of the opinion that large potential changes, at least, are indicative of fundamental change in the metal reactivity. Another experimental approach which might be used to give similar information, but without the possibility of the dual interpretation, is that of measuring the contact potential (see above) of a metal as a function of material adsorbed on it. The experimental method measures the electrostatic difference of potential between two metal surfaces separated by a small air (or other gas) gap. If one metal is maintained as a standard, the effect of adsorbed materials on the other can be followed by the change in contact potential. The method has the advantage of eliminating the possibility of measuring resistances, since there is no current flow even to the

extent of that needed to activate a galvanometer. Also, the potential is measured in the absence of the solution so that local currents on the metal and the possible continuing influence of the solvent are not complicating factors.

The distribution of sorbed material might be determined by scanning the galvanic potential of the metal surface with a probe electrode but a more effective way, where applicable, is by use of radioautographic techniques. This consists of first exposing the metal to solutions containing tagged inhibitors for the requisite time. After removing and drying, the metal with the attached radioisotope-containing material is placed in contact with specially prepared photographic plates which are sensitive to nuclear rays. In the absence of alpha particles $\beta$ decay isotopes can be used very effectively in this procedure. The radiotracer leaves an imprint on the plate which is a replica of the portions of the surface on which they are adsorbed.

The type of film, i.e., orientation of the individual molecules, extent of packing, number of layers, can be deduced from the amount of adsorption and the true surface area provided by the metal. A considerable amount of information of this type can be derived from electron diffraction patterns obtained by reflection of a low-angle incident beam from the metal surface.

Another approach to the study of adsorbed films in relation to corrosion inhibition is provided by considering the wettability of the metal surface. On one hand, contaminated surfaces might not accept inhibitor molecules until the contamination is displaced, hence a detergent might be mixed with an inhibitor to make it effective in practice. On the other hand, some workers consider that an inhibitor might function by making a metal surface hydrophobic. In either event, the investigation of the property is desirable. To provide a completely quantitative basis for wettability, surface tensions for the solid surfaces are needed, but these, unfortunately, are not available or measurable. A less exact relationship depending on the contact angle can be used. This is not a fully effective criterion because of poor reproducibility, because the angle is not a sensitive function of small changes in composition and because resolution at small angles in particular is not possible.

Most of the discussion on interfacial phenomena has had implicit in it the fact that the measurements are made on equilibrium systems. This is far from the case in most corrosion systems and so a general complication must be kept in mind. The response of these systems to the presence of inhibitors might be influenced more by the early history of the sorptions than on the status which might be attained finally. For instance, adsorption out of concentrated solution can be temporarily totally reversible, whereas out of dilute solution of the same components some portion may be irreversibly adsorbed. This has been ascribed to slower orientation on the surface of the metal from more concentrated solutions.[7]

*Specific Studies*

The number of different approaches found in the literature indicates the variety of phenomena involved. This may best be illustrated by considering several researches on the same, or similar, material.

**Chromate**—Pourbaix and Van Rysselberghe[8] discussed this inhibitor in terms of an electrochemical mechanism in which they sum the current requirements for all of the possible reduction processes. The emphasis was on the effects on the solution side of the interface. Mears and Brown[9] also interpreted chromate effects in terms of an electrochemical mechanism, but in this case from the point of view of the electrochemistry of the metal. They described the changes taking place at the local elements and concluded that chromate polarizes the local anodes but causes some depolarization of the local cathodes. It is clear that there is some overlap between the ideas of these two sets of investigators.

The literature also contains conflicting opinions regarding the non-electrochemical aspects of this inhibitor. It has been suggested that

a) it functions by virtue of its oxidative ability and precipitates mixed oxides of chromium and the metal it protects, e.g., iron or
b) it adsorbs and in so doing reduces the intrinsic reactivity of the metal.

Certainly these two mechanisms are not mutually exclusive. The presence of visible insoluble reduction product is easily demonstrable even when the material is used in acid solutions, and an explanation for this type of inhibiting action has been offered on the basis of the kinetics of the chemical reaction. The diffusion rates in solutions, and especially in the liquid film just adjacent to the metal, have been suggested as providing the ultimate control of rate when visible solid corrosion product is formed.[10] The adsorption of chromate containing the radioisotope chromium-51 on steel has been determined and its distribution has been observed by radioautographs.[11] The pick-up so observed appeared to be less than a monolayer, but it had a very marked effect on the metal as shown by the large changes it produced in the contact potential of the metal.

The chemistry of precipitation enters the picture as shown by Palmer[12] who suggested that frequently the mixed iron and chromium oxides formed gelatinuous membranes over anodic area and that these were more permeable to chloride than to chromate unless a high $CrO_4^{=}/Cl^{-}$ ratio was maintained. He proposed that addition of phosphate containing materials would make the precipitate more crystalline and allow for denser packing on the surface, thereby decreasing permeability to detrimental ions. The use of the mixed material was indeed more effective. This was also shown experimentally by Kahler and George[13] with the same kind of system, but they provided an explanation based on the sequestering properties of molecularly dehydrated phosphates.

**Nitrite**—Cohen and co-workers[14] postulated that the nitrite ion first adsorbed and then reacted to make the film originally formed in air more protective. Wyllie and Cheesman[15] are in reasonable agreement with this idea for steel in synthetic sea water. They say that nitrite ion is an anodic inhibitor which forms a thin, semi-protective film. From their data it is

possible to draw the inference that inhibition is caused by, or is aided by, nitric oxide which is a reduction product of the primary reaction. Another point of interest reported in this work was that nitrite and phosphate together are more effective than either one alone. This is in line with the effectiveness of the combination mentioned earlier and with the growing tendency to use mixtures of compounds as inhibitors.

**Polar Organic Compounds**—Papers dealing with the direct inhibitive effects of organic materials under a wide variety of conditions are too numerous to detail here. Instead there are given below a few researches which illustrate the physical chemical aspects mentioned briefly earlier.

When these materials are adsorbed on the metal surface they may simply provide a blanket which separates the reactants, the blanket may provide additional electric resistance in the local cell circuit, or the individual adsorbed particle may polarize the individual metal atom to which it is attached (equivalent to saying that it influences the intrinsic reactivity of the metal). Which of these functions the molecule performs best on a given metal should be a characteristic of its molecular constitution. Some functional groups are held more firmly than others[6] and the presence of more than one functional group on a molecule can improve the bond by serving as an additional anchor or by causing changes in the electron density of the molecule so as to make the original functional group more reactive. For a given functional group the molecular weight and the geometry of the molecule are factors as shown by Mann[16] and by Cavallaro[17] among others. Most explanations regarding the effect of side chains have been based on the area of surface covered by each molecule. This explanation overlooks the fact that aggregation in solution would be diminished by increasing assymetry of the molecule. In essence, branched chain molecules and the like provide a greater effective concentration of monomer for adsorption at all solution concentrations.

Adsorption of polar organic compounds out of solution has been determined by weight increase[6] and by change in solution concentration.[18] In the latter, Greenhill made use of a hydrophil balance to determine concentration decrement by change in surface tension. Properly used, this is a very sensitive method and is capable of showing small changes in very dilute solutions. There has been some use of $C^{14}$-tagged compounds to study adsorption on metals, but it has not yet been widely reported largely because of counting difficulties with the weak beta emitter and the over-all small pickup. Stearic acid with the radioisotope in the carboxyl group has been under study here for some time, but so far has been useful only to check isotherms obtained by weight gain methods.

The relationship between adsorption and inhibition can be established by measuring the effect of the adsorbed material on the rate of a given reaction. For instance, the rate of hydrogen evolution from the reaction of aqueous 4 N HCl with steel powder which had adsorbed on it one or more compounds was compared to the rate using fresh steel powder.[6] Interestingly enough, it was found that most of the effect in reducing the reaction rate was caused by the invisibly adsorbed material. The much larger amount of physically held material supplied relatively little of the inhibiting power. It is important in considering this fact to keep in mind that the corrosive medium used was very aggressive. In less severe surroundings the efficiency of the physically adsorbed material would be proportionately more noticeable.

Adsorbed films of the type under consideration here have been investigated by electron beam diffraction using both reflection and transmission methods. This tool has been used primarily in fixing the orientation on the surface but can be useful also in distinguishing between monolayers and polylayers.[19] In one case the rate of orientation was actually followed directly on the viewing screen of the diffraction instrument.[20]

Wetting characteristics have been studied as in the sessile drop method used by Rogers and Waldrip.[21] Cardwell and Eilers[22] combined a wetting agent with an inhibitor and found definite improvement, probably because the wetting agent displaced surface soil and allowed the inhibitor to get to the metal. Zisman and his co-workers have described metal surfaces with both hydrophobic and oleophobic characteristics after exposure to polar solutions of organic compounds.[23] Wostenholme and Shluman[24] determined contact angles caused by various compounds adsorbed on evaporated metals in the absence of oxygen. They were interested in the angle as a function of both concentration and time. One interesting observation they report concerns the retardation and even prevention of adsorption of some organic materials in the presence of sulfate ions. This suggests the problems of competitive adsorption which have not been stressed here but which are important to this field, for example, with respect to the influence of chloride ion on the effectiveness of many inhibitors.

Adsorption has been indicated indirectly according to some workers by the effect an inhibitor molecule has on the galvanic potential of a metal. Mann[25] was firmly convinced that amines had only a cathodic effect on steel, but others (7, Sudbury) interpreted the evidence to show that the effect was both anodic and cathodic. The charge on the cationic amine in itself does not mean that it is transported to the cathodes since ions may be so large that they carry little or none of the current. Swearingen and Schram[26] also consider that amines have cathodic effects but used cathodically polarized steel just as Mann did and so could not have shown anodic effects. They did conclude that adsorbability rather than size and shape of the molecule was the important factor. Cavallaro[17] used potential changes to conclude that alkyl thiocyanates and thioureas acted on both types of local electrodes when used with steel.

Hurst and Jermyn[2] studied the kinetics of the reaction between magnesium and acetic or sulfuric acid and, on the basis of the effect of amine inhibitors on the order of the reaction and on its activation energy, concluded that the size and shape of the amine were

the determining factors. Thus, they suggested that the film acted as a blanket with no effect on the metal itself.

The experimental evidence shows that the inhibitive effect may be attributed in part to blanketing by an adsorbed polylayer which impedes diffusion. This type of inhibition is satisfactory provided the inhibitor can be made to stay on the metal or can be replenished. This means that competition for the particle between the surface and the solvent is important, or in other words variation in solubility must affect the adsorption. Further, molecules adsorbed in this way are rather easily displaced and could be made ineffective by the presence of contaminants even in very low concentration. The type of inhibitor which is chemisorbed can be effective with even less than a monolayer present. It would be more permanent, less sensitive to environmental changes and would produce from the solution side the same effect on the surface atoms as an imposed current or an alloying constituent does from the metal side. In the final analysis, blanketing action by one molecule while a second undergoes the more time consuming operation of chemisorption appears to offer a profitable approach.

## Conclusion

The various approaches appear at first glance to lead to divergent views but a careful study of the literature reveals that many of the conclusions are interlocking. The arguments are vigorous and the evidence cited is not always unequivocal, but each probably has some part of the correct answer. With sufficient detail available, it will become possible to tie most of the loose ends together.

Complete corrosion inhibition probably requires stoppage of more than one process plus assistance in preserving the true inhibitor particle and getting it to the proper site. Thus, the use of several materials in one inhibitor might have been predicted on theoretical grounds. It is not unreasonable to suggest that with sufficient knowledge regarding the corrosion reaction in any given system, it should be possible to write a 'prescription' for an inhibitive mixture to take care of that system. This is contrary to the desire to have a universal remedy, but it is not likely that there is such a remedy by chemical treatment.

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## DISCUSSION

**Question by H. H. Uhlig, Massachusetts Institute of Technology, Cambridge, Mass.:**

Is the $CRO_4$ adsorption isotherm reversible?

**Author's Reply:**

The chromate which was picked up on the metal by the method used was not removable by washing with distilled water. Any which might have been removable was carried off when the sample was taken from the chromate solution rinsed and then wiped dry with filter paper. Since the uptake was determined by counting the metal surface this necessitated that all excess solution be removed or some activity would be deposited by crystallization.

From B.E.T. areas using krypton it was determined that a full monolayer of undesorbable chromate was on the surface of chromium metal so in this case any physically adsorbed material would not be likely to have a profound effect on the metal properties.

It should be noted that the metals were not reduced and presumably had an oxide layer on them. In view of the prevalent notions of the passage of cations through oxide films there should at all times be some fraction of metal ions in the surface and available for attachment of sorbing particles. Speculatively, for a long enough time every cation which comes to the surface might acquire a chromate ion and so at equilibrium the net result would be the same as if oxide-free surface were originally exposed. There would, of course, have to be a difference in the rate of attainment of equilibrium.

**Question by Ivy M. Parker, Plantation Pipe Line Co., Bremen, Ga.:**

Can you distinguish a difference between degree of difficulty of removal of different inhibitors on different metals?

**Author's Reply:**

Theoretically these distinctions could be made pro-

vided there was a large enough change on desorption to be determined by the counting procedure. In the present case only chromate was used but both chromium and steel were exposed to it. There was no appreciable difference with the two metals.

**Question by Milton Stern, Massachusetts Institute of Technology, Cambridge, Mass.:**
Are you familiar with work which has attempted to correlate surface tension measurements with adsorption using the Gibbs adsorption equation? What are the experimental difficulties?

**Author's Reply:**
If the surface tension measurements refer to solids the answer is that such reports as are in the literature are not useful on a quantitative basis. Some efforts have been made to use the Gibbs' equation by using the quantity adsorbed for the "excess surface concentration" and calculating $d\delta/dc$. In addition adsorption at a mobile interface, liquid-air, has been determined by radiotracer technique [*Nature* **163,** 845 (1949).] The isotherm did not flatten as it should according to the Gibbs' equation, indicating that there was more than one layer even at a solution surface.

Surface tensions of solids are determined indirectly by measuring the coiling of very thin foil or from heats of solution of very finely divided solids or a number of other indirect methods. None have been found to be either reproducible or precise. Measurement of liquid tensions depends on the mobility of the medium and similar methods have been used with molten metals. Even determining the latter as a function of temperature is of no value because of a discontinuity of at least a change in slope at the melting point.

**Question by George E. Best, Mutual Chemical Co., of America, Baltimore, Md.:**
With reference to the chromate firmly attached to chromium metal, was it ascertained that none of the hexavalent chromium had become reduced to the trivalent form?

**Author's Reply:**
The only evidence that it remained as hexavalent chromium was that no exchange was obtained with chromium-III in solution. Indirect evidence supporting the hexavalent form on the surface was that there was only a monolayer of the material and that a few exploratory experiments indicated that chromium-III was not as firmly attached to the metal surface on adsorbing from chromic ion solutions and then washing.

# Corrosion Problems of the Railroads ★

*By L. S. CRANE**

**Abstract**

Corrosion losses to American railroads are estimated at $268,000,000 annually. Major corrosion problems of railroads and remedies are listed including bridge painting, brine drippings damage, car painting, steam boiler corrosion cracking, Diesel engine corrosion difficulties with cylinder liners, bearing and injection systems, trackage losses from stress, humidity and mechanical deficiencies. Time to do certain kinds of corrosion preventive work is given and the work of the American Railway Engineering Association in redesign of rail fillet area to give better stress distribution is mentioned.

THE DICTIONARY has this to say about corrosion: ". . .now generally used of a gradual wearing away or disintegration by a chemical process, as in the rusting of iron. . ." This may be due to chemical or electrochemical reaction with the environment.

It is probable that no single industry uses a greater tonnage of metal products nor a wider variety of these products than do the railroads. Locomotives and cars, buildings, track, bridges and other roadway structures account for practically all of the railroads' requirements in metals. They have done so for many years and the railroads have always been conscious of the terrific loss and damage resulting from corrosion. It cannot be said, however, that the railroads have ever before been so interested in the prevention of corrosion through proper utilization of materials and protective design.

No useful purpose can be served by wondering whether the railroads should have started years ago to make intensive studies of corrosion prevention. Certainly, they are doing it now. For example: Mr. F. K. Mitchell, manager of equipment, New York Central Railroad, presented data recently to the Car Department Association of St. Louis outlining some of the things his railroad had learned about corrosion losses. The ratio of corrosion damage to total repair costs on various types of rolling stock was found to be, approximately: 64 percent on hopper cars; 58 percent on gondola cars; 19 percent on box cars; 8 percent on flat cars; 25 percent on passenger coaches, and 40 percent on baggage cars.

These are shocking figures. About one-third of every freight car repair dollar is paid out to restore corrosion losses. On passenger cars corrosion losses represent about twenty-five cents out of every repair dollar.

Extending these figures to the total freight and

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* Engineer of Tests, Southern Railway System.

passenger car repair bills of American railroads in the year 1950, we find that corrosion costs about $199,000,000. Figures for maintenance of way and structures expenditures can be calculated roughly to represent an additional out-of-pocket payment due to corrosion of about $69,000,000. The staggering total of $268,000,000 represents a lot of good railroad money "rusting away." Small wonder that a problem of such magnitude is receiving thoughtful consideration and study—and that determined action is being taken to reduce corrosion losses.

One of the major problems for railroads is the protection of bridges and other structures built of metal against atmospheric corrosion. There are many thousands of bridges on the American railroads, all commonly protected by painting. On the Southern, we have established the expected life of a paint coating on a bridge to be between seven and eight years.

Painting of a large bridge is a major project in itself and costly in materials and labor. For example, 19,000 gallons of paint were required for the painting of a new bridge over the Cumberland River near Burnside, Kentucky, completed by the Southern in 1950. With paint weighing 10 pounds per gallon, 190,000 pounds of paint were used, which, by itself, represents a great structural load on the bridge. It took 30 men six months to paint this bridge, and it is estimated that a normal maintenance crew will require two years to repaint the bridge beginning, probably, in 1957 or 1958.

It is our practice to use only the best quality paint on bridges after preparation of the metal surfaces by flame cleaning, chipping and wire-brushing to remove all scale. Since surface preparation must be done in the field, the task is not an easy one.

Frequently, high humidity atmospheric conditions complicate the task of getting good adhesion as paint coats are applied. And, not infrequently, rain often requires that work be abandoned for days at a time. These and other factors all enter into cost calculations and make it important that paint as applied protects the surface for as long a period as techniques of preparation of surfaces, application methods and paint quality control will permit.

The usual practice in painting bridges is to use a good grade of red lead or zinc chromate primer followed by two coats of a black paint (such as graphite or carbon black), or aluminum in a synthetic resin vehicle.

Protecting bridge floor beams, top chords and cross stringers against corrosion is very difficult. Brine drippings from refrigerator cars, for example, are extremely corrosive and the parts named are particularly vulnerable. They are usually protected with petrolatum, asphaltic or bituminous type coatings. Unfortunately, this protection lasts only from two to four years since the coating is rubbed off by the creeping of the ties. Corrosion resistant sheets have been tried between the ties and top chord members but do not afford complete protection. Although the ties are anchored, the sheets may crawl. The holes through which they are tied are elongated and then permit water to pass through to set up corrosive influences on the structure itself.

The best possible surface preparation for painting is considered to be well worth what it costs on the Southern. For this reason, it follows the practice of completely sand blasting all freight cars to bare metal before paint coats are applied. This assures us of obtaining a good bonding of the primer coat and an over-all better appearance on the finished cars.

Most railroads are using synthetic paints for box cars. Normally, they are made of varnish-type vehicles with synthetic resins and natural drying oils pigmented with iron oxide or other compounds. Such paints are adequate for the four or five year protection period involved in the usual cycle of car painting on the railroads.

There are, however, many cars which go well past this period without receiving painting attention. Cars with as much as half the exterior paint removed are not considered in bad order according to Association of American Railroads rules and such cars need not be returned to the owning railroad for painting. As a result, many cars go for eight or ten years without painting maintenance. Corrosion's effects on the unpainted areas frequently necessitate that side sheets be renewed when cars are returned to the owning lines.

Paint coatings on open-top cars are often severely abused by shippers who use them for hot loads and corrosive materials. It is common practice to use hopper cars without any protective coatings on the inside of the cars (some railroads apply a single coat) because of the abrasive or corrosive effects of ladings. Atmospheric exposure, alone, results in some corrosion damage. Often, slope sheets and hopper sheets and the bottom portions of side sheets are made extra thick to withstand corrosion for a longer period. Low-alloy, high-tensile steels having superior corrosion resistance often justify their additional cost in these same applications by prolonging life of car body members.

The corrosion damage that occurs in passenger car equipment is even more malignant by reason of the fact that most of it is concealed from view. With the advent of streamlining it has become standard practice for the railroads to keep their rolling stock much cleaner than ever before. This means that it is being washed much more frequently and washed with cleaners which may increase the rate of corrosion unless they are used under the most carefully controlled conditions.

A serious example of this type of corrosion was discovered when the Southern removed exterior stainless-steel sheathing from one of its passenger cars that had been in service about seven years. The car framing was made of a low-alloy, high-tensile steel. The framing was found to be so badly corroded that it caused serious alarm and remedial steps were taken immediately. Damage resulted largely because caulking material in the snap molding had not been effective in keeping moisture and cleaning compounds out.

Protection against this hazard is now afforded by coating structural members with two coats of zinc chromate primer and a top coat of bituminous asphalt. Some new caulking compounds with rubber and

asphalt bases are also being tried. On new cars, the Southern has gone to the expense of putting a solid girder piece of stainless steel all along the side of each car under the side fluting to withstand corrosion. Good design and careful caulking are proving effective in eliminating corrosion around window frames.

The problem of intercrystalline cracking in boilers on steam locomotives has not been completely solved, although its importance is dwindling due to the increased use of Diesel engines. Problems of corrosion fatigue, stress corrosion cracking, cavitation erosion and fretting corrosion, are all encountered in steam locomotives. Corrosion problems did not disappear, however, with the advent of Diesel locomotives. Corrosion was encountered from cooling water, which has now been minimized by treating the water with alkaline sodium chromate solution in a concentration of 200 parts per million. However, with chromate becoming increasingly scarce, water treating companies are now trying to develop a satisfactory substitute. Diesel cylinder liners have given considerable difficulty with cavitation corrosion. In some cases liners have failed in seven to fourteen days. This also has been minimized by use of sodium chromate inhibitors.

Auxiliary boilers to provide steam have had boiler coils fail through corrosion resulting from the presence of dissolved oxygen in the water and also from the acid wash used periodically to remove deposited scale within the boiler. If given proper care, boilers should be rinsed out after scale removal with an alkaline solution to neutralize the acid. Failures resembling stress corrosion cracking have occurred in the coils in boilers. When stress is applied from the heat impinging upon the coil, the coil will expand causing cracks to form in the decarburized outer surface and progress through the entire wall until failure occurs. A suggested remedy is the use of coils made of alloy steel tubing. Experiments are being carried out at the present time with these materials.

It has been found that the high pressure fuel lines on certain makes of Diesels are subjected to internal pitting which has been identified as cavitation erosion by some investigators and attributed to the vibration frequency of the engine while others have felt that it is due to the alternate cycling between extremely high pressures of several thousand pounds per square inch in the tube just before the fuel is injected into the cylinder to a slight vacuum just after the injection. The latter feel that the tube is stretched under the high pressure part of the cycle and returns to normal under the vacuum portion.

There is also a quite severe corrosion problem within the engine itself from the metallo-organic additives found in the modern lubricating oils, particularly on the silver wrist pin bushings found in some Diesel engines. There has also been some corrosion found on the lead bearings which is caused by some irregularity in the operation of the unit.

Tracks also suffer from corrosion. One of the best examples of fretting corrosion cracking can be found in the rail joints where the expansion and contraction of adjacent rails as well as movement caused by car wheels passing over the joint result in high rates of wear in the joint areas.

There are also corrosion problems associated with rails caused by brine drippings from refrigerator cars, leachings from coal cars, moisture in tunnels and fretting corrosion of the fishing surfaces under joint bars. The problem of corrosion caused by brine drippings from refrigerator cars has been under investigation by the Association of American Railroads for some years and it has developed inhibitors which when added to the brine drippings alleviate their corrosiveness. An extensive test is now under way to determine the effectiveness of these inhibitors under actual service conditions.

The corrosion of the rail web is a very serious problem since corrosion fatigue cracks develop around the bolt hole in the web of the rail. As the splice bar which joins the rails is tightened up, it produces a wedging action which tends to pull the railhead from the flange and produces high tensile stresses in the rail web. As the rail slides in and out, high bearing pressures are developed on the sides of the holes by the bolts. As train loads pass over the rail, the web is subjected to alternate cycles of compression and tension. When corrosion reduces the thickness of the web at the hole thereby reducing the endurance limit of the joint, fatigue cracks occur due to failure of the steel to withstand the high cyclic stresses.

Tunnels are a very serious source of excessive corrosion of rails. It is not unusual to lose as much as one-half inch in height in the railhead by wear in a period of three or four years. High humidity in the tunnel plus corrosive ingredients in the smoke form a thin layer of rust on the rail which is then polished off as the train goes over it. Some railroads use welded rail joints throughout tunnels, but even these may develop crossion fatigue cracks.

Tests run in cooperation with the American Railway Engineering Association, the University of Illinois and the Pennsylvania Railroad have indicated that the endurance limit of the rail steel could be very substantialled reduced under certain corrosion conditions. Measured static or dynamic stresses on uncorroded rails could not cause failure in the web fillets. However, when the endurance limit is reduced by corrosion to a low level, the measured stresses are high enough to cause cracking. The results of this work have led to a redesign of the section to improve the stress distribution through the fillet area.

Considerable work has been done by the American Railway Engineering Association in the application of various protective coatings such as petrolatum, bituminous materials, etc. Some railroads are painting all of the welded rails in tunnels.

One more attack of a general nature can be made against the problems of corrosion. Accurate record keeping on all railroad will tend to identify the extent of corrosion losses and many of the causes. Working from these records, it will be possible to develop remedies.

When we consider that we are dealing with a loss due to corrosion of over a quarter of a billion dollars per year in the railroad industry alone, it would certainly seem that we could afford to put into effect the mot advanced techniques for the reduction of corrosion damage.

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Topic of the Month

# Galvanic Behavior of Tin Dipped Coatings on Copper Alloys

By F. L. LaQUE*

SOMETIMES copper and copper alloys are given a protective coating of tin or a lead tin alloy applied by dipping into the molten metal. As applied, these "tin" coatings can be expected to be anodic to copper and copper alloys in most environments. However, under some circumstances, the coatings can, and do, become cathodic to the basic metal and, in this condition can, and do, accelerate corrosion in the form of pitting or other forms of localized attack at the base of pores, scratches or other holidays in the tin coating.

A classic investigation of this phenomenon was undertaken by Dr. P. D. Merica at the National Bureau of Standards[1] to account for the perforation of tinned copper roofing sheets. Merica attributed the effect to the development of a relatively noble tin copper alloy by diffusion. This was referred to also by A. W. Tracy in a later discussion of a paper on potentials of metals in sea water.[2]

The present author and his associates have become convinced that these tin coatings, as well as those of the lead tin alloys, such as wiping solder (60 percent Pb, 40 percent Sn) can form corrosion product films that can make them more noble without any effect due to the alloy layer near the interface between the coating and the basic metal.

There is shown in the figure the drift in potential towards more noble values of a tin coating on a 70:30 cupro nickel alloy and wiped solder coating on Monel immersed in flowing sea water at Kure Beach, N. C. Similar tests on the 60:40 wiping solder have shown potentials as low as 80 millivolts vs. calomel after five months.

The fact that by scraping off the corrosion product film the normal potential values in excess of 400 millivolts can be restored is evidence that it is this film rather than any alloy layer that is responsible for the noble potential in this case.

*In charge of Corrosion Engineering Section, Development and Research Division, The International Nickel Co., Inc., New York, N.Y.

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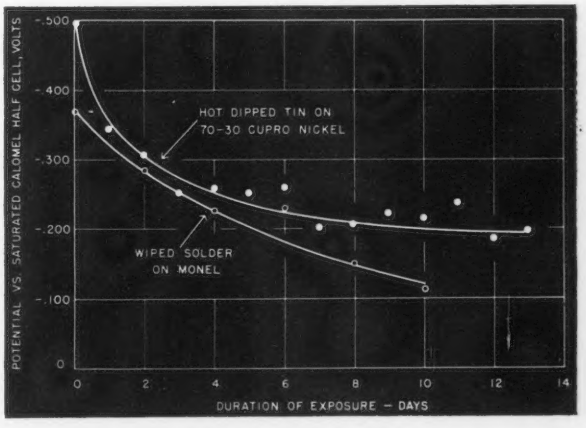


**Figure 1—Open circuit potentials of "tinned" surfaces in flowing sea water.**

# NACE News

## Attendance Is Near Record at February Philadelphia Meeting

Near record attendance was present at the first regular meeting of Philadelphia Section at Poor Richard Club, Philadelphia February 8. Recently elected officers presided for the first time.

Material differences between the problems of designing cathodic protection systems to protect underground metal in metropolitan areas and those for designing systems to protect single lines in cross-country service were explained by E. R. Shepard, consulting engineer for Hinchman Corp. of Detroit. Mr. Shepard's explanation of complex controls and arrangements to prevent damage to nearby structures received close attention and evoked many questions. His topic was "Application of Cathodic Protection to underground Utility Structures in Metropolitan areas."

Robert R. Pierce, Pennsylvania Salt Manufacturing Co., Philadelphia opened his portion of the technical program by showing a motion picture of the construction of a vat in pre-war Germany. Mr. Pierce explained the methods used and described the materials and their purposes in the construction of the vat which was intended to handle acid slurry in manufacturing black powder. He told of several imported patents and methods his company is using.

Mr. Pierce, chairman of TP-6K on Corrosion Resistant Construction with Masonry and Allied Materials, displayed wide knowledge of his subject in answering questions by his audience. His topic was "General Fundamentals of Design and Material Selection of Corrosion Resistant Masonry." He gave information on the life expectancy, limiting temperatures, and service of the various masonry materials used for specific processes. The use of masonry, including carbon brick, was cataloged as a protective coating in preserving the supporting structures from deterioration. He ended his discussion by showing a series of slides depicting companion applications in construction of stacks and their use in air pollution control.

## Kulman Talks at N. Y.

F. E. Kulman of Consolidated Edison Co. of New York discussed "Microbiological Corrosion of Buried Steel Pipe," at a March 6 meeting of Pittsburgh Section at Mellon Institute.

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Nearly all technical papers presented at annual meetings of NACE are published in Corrosion after review by the Editorial Review Committee of the association.

### NACE MEETINGS
### CALENDAR

**April**

3—Pittsburgh Section. Evaluation of Tapes as Protective Coatings, Carl Johnson, Minnesota Mining & Mfg. Co.

7—North Texas Section.

8—Houston Section. E. Q. Camp, Humble Oil and Refining Company, Baytown, "Graphite Precipitation-Migration in Low Pressure Atmospheric Temperature Refinery Vessels." Floor discussion, P. E. Darling, Pan American Refining Co., Texas City. An exhibit of specimens will be provided.

15—Chicago Section. Aaron Rabinkoff, Products Pipe Line Department, Standard Oil Company will speak on solution of internal corrosion of pipe lines of finished petroleum products by dehydration.

17—Baltimore Section. S. A. Williams will speak on protective plastic coatings.

23—Metropolitan New York, H. H. Uhlig, Massachusetts Institute of Technology; T. Zajac, Shell Oil Company. Motion picture "Corrosion in Action," T. P. May, International Nickel Co., Inc.

26—Sabine-Neches Section. Field trip, Magnolia Petroleum Refinery, Beaumont, Texas.

29—Southwestern Ohio. "Industrial Waste," by Arthur Caster, Waste Disposal Engineer, City of Cincinnati, Ohio.

**May**

1—Pittsburgh Section. Corrosion of Underground Structures by Stray Currents, Norman Peifer, Manufacturers Light & Heat Co.

5—North Texas Section.

13—Houston Section. Studies of High Pressure Sweet Oil Corrosion, H. L. Bilhartz. Discussion by R. C. Buchan. A display of specimens is planned.

15—Detroit Section.

20—Chicago Section. Round table discussion on general Corrosion problems.

## Neoprene Discussed

"Neoprene and Other Elastomers as Corrosion Resistant Membranes," was the topic of a discussion by Louis S. Bake of the E. I. DuPont de Nemours and Co. rubber laboratory before the January 21 meeting of Greater St. Louis Section. Formation of membranes of Neoprene, methods of securing adhesion, application, corrosion resistance and service life when applied to metals and other surfaces, with other elastomers and with paints were described.

## Phosphatizing Research Talk Featured at Baltimore Section

Mrs. Jeanne Burbank of the Naval Research Laboratory, Washington, presented an interesting and informative talk on basic research on phosphatizing at a meeting of Baltimore Section. It was held at Park Plaza Hotel, Baltimore.

Next meeting of the section is scheduled April 17 when S. A. Williams of Baltimore will speak on protective plastic coatings for metal and concrete. Mr. Williams, an applicator of plastic coatings, has previously addressed representatives of the Bureau of Yards and Docks at a Washington meeting, discussing surface preparation and the suitability of various coatings.

The section also has tentatively scheduled dinner meetings on October 7 and November 21. The latter meeting, planned as a joint meeting with American Chemical Society, is scheduled to hear F. L. LaQue of The International Nickel Co., Inc.

## South East Region Elects New Officers

New officers have been elected for South East Region as follows: R. A. Davis, Chicago Bridge and Iron Co., Birmingham, Ala., chairman; Jack West, Aluminum Company of America, Atlanta, Georgia, vice-chairman and H. C. Van Nouhuys, Southeastern Pipe Line Co., Atlanta, secretary-treasurer.

E. D. McCauley, American Cast Iron Pipe Company, Birmingham, Ala. has been elected to fill the unexpired term of A. R. Swanson, resigned. E. C. Range of Okonite Company, Atlanta, was named temporary director until the election to fill the unexpired term could be held.

## Southwestern Ohio Meets With ASM

A joint meeting with American Society for Metals was held by Southwestern Ohio Section NACE January 10 at American Engineers Society Building, Cincinnati, Ohio. Twenty-three members and 63 guests heard F. L. LaQue of International Nickel Co. speak on "Corrosion by Electrolysis."

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Single copies of most back issues of Corrosion are available to NACE members at 50c each and to non-members at 75c each.

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## Maracaibo Oil Field Corrosion Discussed

H. L. Bilhartz, recently returned from a trip to Venezuela showed colored slides of oil production in Lake Maracaibo and in other parts of Venezuela to members of North Texas Section at a meeting Monday, March 3. Human interest and scenic photographs also were shown.

Slides depicting pipe laying operations with emphasis on field joints were shown. Mr. Bilhartz reported corrosion to flow lines alone costs $1,000,000 in the operations at Lake Maracaibo where approximately 500,000 barrels of oil daily are produced. Production is from wells in water 60 to 90 feet deep with outpost wells currently being drilled at 99 feet.

## Contractor's Viewpoint Is Topic at Tulsa

About 90 persons were present at a joint meeting of Tulsa Section NACE and the Pipe Liner's Club February 18 at the Mayo Hotel, Tulsa. Rolit Lennart of the Pipe Liner's Club called the meeting to order after which Don B. Good, secretary of the Pipe Liner's introduced guests.

Clyde Wyant spoke on "The Pipe Line Contractor's Viewpoint of the Owners and Their Employees," after which there was a question and answer period.

## Logical Painting Plan Urged at Sulphur Meeting

Paula R. French of Humble Oil and Refining Co., Baytown Refinery addressed 25 members and 20 guests at a buffet supper meeting of Sabine-Neches Section February 28 at Sulphur, La. His topic was "Painting for Protection."

The logic of organizing painting programs by reference to labor and materials data was emphasized by Mr. French. He described practices at his plant, equipment, methods of surface preparation and paint systems.

A color film, "Painting for Protection at Baytown Refinery," was shown. A brief discussion followed Mr. French's talk.

## Cleaning Pipe By Chemical Means Is Shreveport Subject

"Cleaning Pipe by Chemical Methods," by J. M. Smith of Interstate Oil Pipeline Co. and a motion picture on the installation of magnesium anodes were the scheduled technical items on the program of Shreveport Section NACE February 19.

## South Central Region To Meet October 1-3 At New Orleans

The 1952 annual meeting of South Central Region has been scheduled for October 1-3, with headquarters at the Jung Hotel. This annual meeting usually is attended by more than 300 members and visitors and the decision to hold it in New Orleans reflects the growing number of association members in the Louisiana-Mississippi area.

**Teche Section members lined up to register at Lafayette, La., are (left to right) Ray Tuggle and P. B. Cambre, Texas Pipe Line Co., Lafayette; Glenn E. Rives, Interstate Oil Pipe Line Co., Sunset La.; R. L. Bullock, Interstate Oil Pipe Line Co., Shreveport, La.; Leo J. Strole, United Gas Corp., New Iberia, La.; M. G. Arnett, Central Louisiana Electric Co., Lafayette, La., and seated, Joseph H. Waterfield, United Gas Corp., New Iberia, La.**

## Officers of New Orleans-Baton Rouge Section Elected February 18

Officers of New Orleans-Baton Rouge Section were elected February 18 at a meeting at Engineers and Architects Club, New Orleans as follows: Philip Wogan, Products-Research-Service, Inc., Westwego, La., chairman; J. T. Martin, The Texas Company, New Orleans, vice-chairman; F. S. Bird, The California Company, New Orleans, secretary-treasurer and R. E. Mitchell, Shell Oil Co., New Orleans, assistant secretary-treasurer.

A open discussion on cathodic protection was held followed by a film on pipeline installation. There were 20 members and 10 guests present.

## *Corpus Christi Mail Balloting Planned*

Corpus Christi Section will ballot by mail for new officers soon. Recommendations of the nominating committee at a February 27 meeting were accepted as follows: John W. Nee, for chairman; C. F. Ward, for vice-chairman; Maurice N. Emery for secretary-treasurer.

L. G. Sharpe of Humble Pipe Line Company spoke to 12 members and 10 guests on pipe line coatings. A lengthy open discussion followed the conclusion of his prepared remarks.

Next meeting is scheduled for March 26.

## Policy Is Changed

A revision of policy respecting the issuance of publication numbers to publications of the National Association of Corrosion Engineers has been made whereby numbers will be issued only to those publications offered for distribution separate from Corrosion magazine.

## *Teche Section Hears Robert L. Bullock*

Teche Section's February meeting featured a talk by Robert L. Bullock, Interstate Oil Pipe Line Company, Shreveport on "Practical Application of Cathodic Protection." It was held at Poor Boy's Riverside Inn, Lafayette, La., with 52 members and guests present.

## Los Angeles Section's Nominations Made

New officers were nominated and seconded for Los Angeles Section at a January 30 meeting as follows: K. T. Manganes for chairman; E. O. Kartinen and S. J. Artese for vice-chairman and S. K. Gally for secretary-treasurer. The meeting, held jointly with Western Region, included installation of regional officers L. L. Whiteneck, Board of Harbor Commissioners, Long Beach, director; W. M. Schilling, Southern Counties Gas Co., chairman; E. H. Grizzard, Signal Oil & Gas Co., vice-chairman and Miss Flora Lombardo, Amercoat Corp., secretary-treasurer.

Ellis D. Verink of Aluminum Company of America, New Kensington, Pa. spoke on uses of aluminum in industry. The meeting was closed after answers were asked from the floor for a list of questions on corrosion posed by Mr. Schilling. There were 74 present.

## Tool Engineers to Meet

Meetings of the American Society of Tool Engineers have been scheduled as follows:

1952—Chicago, March 17-21.
1953—Detroit, tentatively, week of March 16.

## Proceedings of Short Course to Be Printed

Proceedings of the University of California at Los Angeles Short Course in Corrosion February 4-8 are being prepared for distribution soon to those attending, L. L. Whiteneck, past chairman of Western Region NACE reports.

The concensus is, Mr. Whiteneck said, that this course, which attracted students from all parts of the United States and Canada, has laid the ground work for future courses reaching an even higher level of technical training and development.

## Kessler Takes Over As TP-15 Chairman

K. K. Kessler, metallurgist for Baltimore and Ohio Railroad, Baltimore, Md., has been named chairman of Technical Practices Committee 15—Corrosion Control in the Transportation Industries. Merritt A. Williamson, former chairman, will continue to serve as editor of "Railroad Corrosion News Letter," a publication sponsored by TP-15 which is being distributed to operating railroads only. The raidroad news letter will not be available for general distribution. Appropriate parts may be reprinted in Corrosion from time to time to give wider distribution to worthwhile material.

First issue of the news letter dated January, 1952 has been issued and initial publication has been exhausted. Among other information it contains technical articles and digests of technical articles significant to the railroad industry, a review of current work on important corrosion problems, railroad corrosion questions and corrosion references of interest to railroads.


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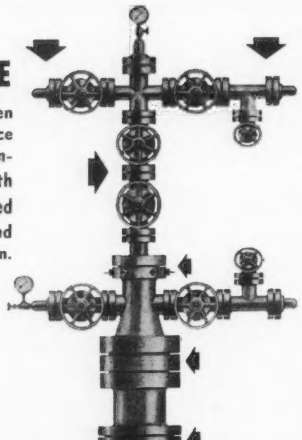

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## AIChE Symposium on Corrosion Set April 21 At Akron, Ohio

American Institute of Chemical Engineers' local sections designated Akron, Cleveland, Pittsburgh, Central Ohio, Ohio Valley and Toledo are participating in a symposium on corrosion at the Mayflower Hotel, Akron April 21.

Registration opens at 8:30 a.m., followed by six papers as follows: James A. Lee, keynote address; R. M. Burns, "Studies of Corrosion Reactions;" Mars G. Fontana, Ohio State University, Columbus, "New Commercial Metals and Alloys for Corrosion Resistance;" W. Z. Friend, International Nickel Co., New York, "Design of Equipment from the Standpoint of Corrosion Resistance;" R. B. Hoxeng, United States Steel Company, Pittsburgh, "Corrosion of Ferrous Metals;" and a talk on cathodic protection by a speaker from Dow Chemical Company.

A prominent Akron rubber company executive is expected to be luncheon speaker. Robert C. Stell of Goodyear Tire and Rubber Co. and Walter M. Otto of Firestone Tire and Rubber Co. are co-chairmen of the symposium.

## API Products Pipe Line Session Lists Corrosion Topics

Three of the seven tentative technical topics to be discussed at an April 21-23 Products Pipe Line Conference by the American Petroleum Institute's Division of Transportion are related to corrosion. The meeting will be held at the Blackstone Hotel, Fort Worth, Texas.

The program tentatively announced for April 21 by the API Subcommittee on Products Pipe Line Technology includes:

Description of Dehydration Equipment and Practices on Pipe Lines.

A Study of the Causes of Pipe Line River Crossing Failures and Methods of Prevention.

Factors Affecting Conservation of Roof Tankage in Products Pipe Line Operations.

Monday evening is assigned to a group session on safety, an all-day field trip has been arranged for Tuesday to pumping station of Humble and Texas Pipe Line Companies, and a question and answer session is scheduled Wednesday, with a field trip to Sinclair's Fort Worth products terminal and Humble's terminal at Dallas.

# Corrosion Problems

**E. A. TICE, Editor**

Corrosion Engineering Section, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Submit questions and answers for this column in duplicate to the editor. All questions become property of NACE. Questions and Answers may or may not be published under this heading, and may at discretion, be answered by mail directly. Answers to questions are solicited. Authors of questions will remain anonymous to readers while authors of answers may remain anonymous if they request it.

### QUESTION

No. 19—What material other than composite brick-rubber linings can be used in the construction of a tank in which an aqueous 10 percent nitric-5 percent hydrofluoric acid solution at 140 degrees F. is stored? **(Editor's Note:** This question relates to pickling of stainless steel and answers should take into consideration the effect of dissolved metal salts and other variables introduced by the pickling action.)

### ANSWER

**We have had reasonably good success with Type 316 ELC stainless welded tanks for holding hot nitric-hydrofluoric pickling solutions. These tanks are made of ¼ inch thick material and welded with 25-12 Cb or 25-20 Mo electrodes. At one of our plants, one tank gave a service life of 5 years. However, it was necessary to patch some of the welds at approximately six-month intervals.**

**We would recommend trying the above only on relatively small batch type pickling tanks where it is not too much of a chore to repair the corroded welds periodically and where shutdown time does not seriously hold up production. We feel that the best type of tank for a large continuous or batch picklers would be a composite carbon brick-Koroseal lined one. This would undoubtedly be the best especially where expensive shutdowns are liable to occur when it is necessary to patch the welds of the Type 316 ELC tank. Also where the heating of the pickling solution in the Type 316 ELC tanks is done by live steam, the steam inlet pipe should be located so that the steam does not impinge as accelerated corrosion may occur at the point of impingement.—By Arba Thomas, Armco Steel Corporation, Middletown, Ohio.**

### QUESTION

No. 20—What is the best type of paint for chemical laboratory interiors?

### ANSWER

**We have had very good service from chlorinated rubber base paint in our own chemical laboratories. This type of paint has proved very satisfactory for the inside walls and ceilings of our laboratory. It is rather difficult to obtain painters who are willing to apply this type of paint because of the obnoxious and toxic properties of the solvent. When the paint is applied, adequate ventilation for the workman is necessary.—By Arba Thomas, Armo Steel Corporation.**

### QUESTION

No. 24—Occasionally severe corrosion of insulated underground piping occurs as a result of infiltration of water (liquid or vapor) into the mass of insulating material. Is the physical or chemical character of the insulating material a controlling factor in such corrosion, or is this merely a form of "contact corrosion" which is equally severe with all insulating materials? To what extent does this corrosion depend on soil characteristics and/or the composition of the soil water which enters the insulating layer? Are there any published reports dealing with this problem? **(Editor's Note:** The above question is a condensation of a letter which was received from one of our friends across the sea. It originally was directed to the Houston office of NACE prior to the initiation of "Corrosion Problems" and considerable time has elapsed since it was first received. If any of our readers can be of any assistance to this contributor a prompt response will be appreciated.)

### ANSWER

**Some mineral or rock wool insulations are very corrosive to ferrous metal due to their sulfide content. We had one experience of this kind. With the neutral or alkaline types of insulation, the corrosion, in all probability, is due more to contact than to its composition.—By Arba Thomas, Armco Steel Corporation.**

### QUESTION

No. 77—The chemical resistant properties of "Teflon," "Polythene," etc. have been well publicized, as have the methods of flame spraying these ma-

(Continued on Page 6)


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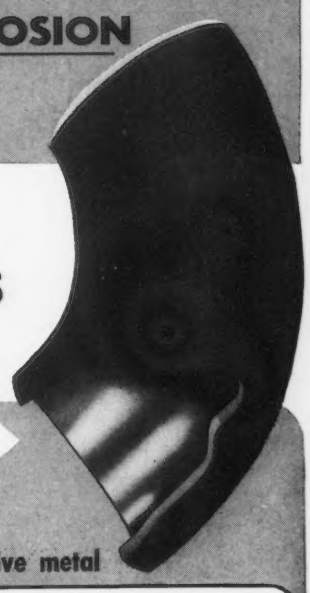

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## Corrosion Problems—

(Continued from Page 5)

terials in metal surfaces. However, do these plastics retain the same characteristics after being flame sprayed? Also, can they be sprayed pin hole free?

ANSWER

**"Polythene" can be flame sprayed with little or no loss of its physical or chemical resistant properties. Such a coating can be applied free of porosity. The questioner is referred to "New Torch Licks Problem of Flame-Spraying 'Polythene.'" By W. B. DeLong and E. V. Peterson. *Chemical Engineering*, 123-25 (1949) June.**

**"Teflon" has not been flame sprayed successfully to date, but can be applied as a water suspensoid with a paint spray gun in coats 0.5-1.0 mils, followed by baking at 750 degrees F between coats. Spark tested coatings ⅞ mils thick applied to steel test coupons have shown exceptional liquid phase corrosion resistance. Water vapor permeability in the vapor phase is a problem with aqueous corrodents, as it is with many organic coatings. Another problem is the susceptibility of the coating to mud cracking if much more than 1 mil is applied per coat.—By T. F. Degnan, E. I. Du Pont de Nemours & Co.**

## Oliver to Address New Orleans-Baton Rouge Section April 21

J. P. Oliver of National Carbon Company, Union Carbide and Carbon Corp., New York will address New Orleans-Baton Rouge Section April 21 at Engineers and Architects Club, De Soto Hotel, New Orleans. A buffet meal will be served. Mr. Oliver's topic will be "Cathodic Protection."

New Orleans-Baton Rouge Section meets regularly on third Mondays monthly at the Engineers and Architects Club.

## Pennsylvania ASM Meeting Set June 20-21

The Eightth Biennial Pennsylvania Interchapter Meeting of the six chapters of American Society for Metals in Pennsylvania will be held June 20-21 at Pennsylvania State College, State College, under auspices of Penn State Chapter.

The technical program arranged includes an address Friday morning by Zay Jefferies on "Metals and Metallurgy of the Future." Two simultaneous sessions will be held on the afternoon of June 20, one on conservation of metals and the other on the relation of laboratory tests to service conditions. On Saturday morning, June 21 there will be concurrent sessions on recent advances in steel-making practice and on the metallurgical aspects of casting.

An informal banquet will be held Friday night. Hotel reservations may be obtained from Prof. H. M. Davis and program details from Prof. J. H. Read, both of the Metallurgy Division, Pennsylvania State College, State College, Pa.

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The 1952 Annual Directory of Membership was published in the March, 1952, issue of Corrosion.

**SEND IN NEWS FOR MAY BEFORE APRIL 10**

## Thermodynamics Report Book Is Offered

Proceedings of the Third meeting of the International Committee of Electrochemical Thermodynamics and Kinetics held at Berne, August, 1951 are available from Marcel Pourbaix, General Secretary and Treasurer CITCE, University of Brussels, Ave. F. D. Roosevelt, Brussels, Belg. or Carlo Manfredi, Editore, Viale Papiniana 57, Milan, Italy.

The 450-page, cloth bound volume covers 35 items under the following headings: General Methods, Behaviors of Metals and Application to Corrosion, Double Electric Couch, Nomenclature and Electrochemical Definitions and Fundamental Bases. Pre-publication price was given as $12, plus 80 cents postage.

## Galvanizers' Committee

The Galvanizers Committee, sponsored by the American Zinc Institute, will hold its 27th meeting at St. Louis, Mo. April 21-22. It will meet at Hotel Statler simultaneously with the American Zinc Institute.


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A Proposed Standard Method for Measuring the Electrical Resistance of Pipe Line Coatings by W. F. Rogers, B. H. Davis, Lyle Sheppard, Donald Bond, L. G. Sharpe, E. R. Allen and P. T. Miller.

Mitigation of Corrosion on City Gas Distribution Systems by A. D. Simpson, Jr.

***Paints and Coatings***

The Effectiveness of Paint in Suppressing Galvanic Corrosion by G. W. Seagren, G. H. Young and F. L. LaQue.

Tests, Properties of Corrosion Preventive Lubricants for Lead Sheathed Cables in Underground Ducts—A Discussion by Howard S. Phelps and Frank Kahn.

***Petroleum Production and Storage***

Corrosion in Condensate and in High Pressure Sweet Oil Wells by R. C. Buchan.

The Use of Ammonia in Control of Vapor Zone Corrosion of Storage Tanks by F. T. Gardner, A. T. Clothier and F. Coryell.

***Miscellaneous***

Causes of Corrosion in Airplanes and Methods of Prevention by N. H. Simpson.

Cathodic Protection of an Active Ship in Sea Water by K. N. Barnard and G. L. Christie.

Corrosion of 18-8 Alloy Furnace Tubes in High-Temperature Vapor Phase Cracking Service by E. Q. Camp, Cecil Phillips and Lewis Gross.

Salt Spray Testing Bibliography by Lorraine Voight.

The Cost of Corrosion to the United States by H. H. Uhlig.

Why Metals Corrode by H. H. Uhlig.

***Reprints of Technical Practices Committee Reports***

Report of TP-12 on Electrical Grounding Practices.

First Interim Report of TP-6G on Surface Preparation of Organic Coatings. Publication 50-5.

Stress Corrosion Cracking in Alkaline Solutions. Report of TP 5 C—Sub-Surface Corrosion by Alkaline Solutions. Publication 51-3.

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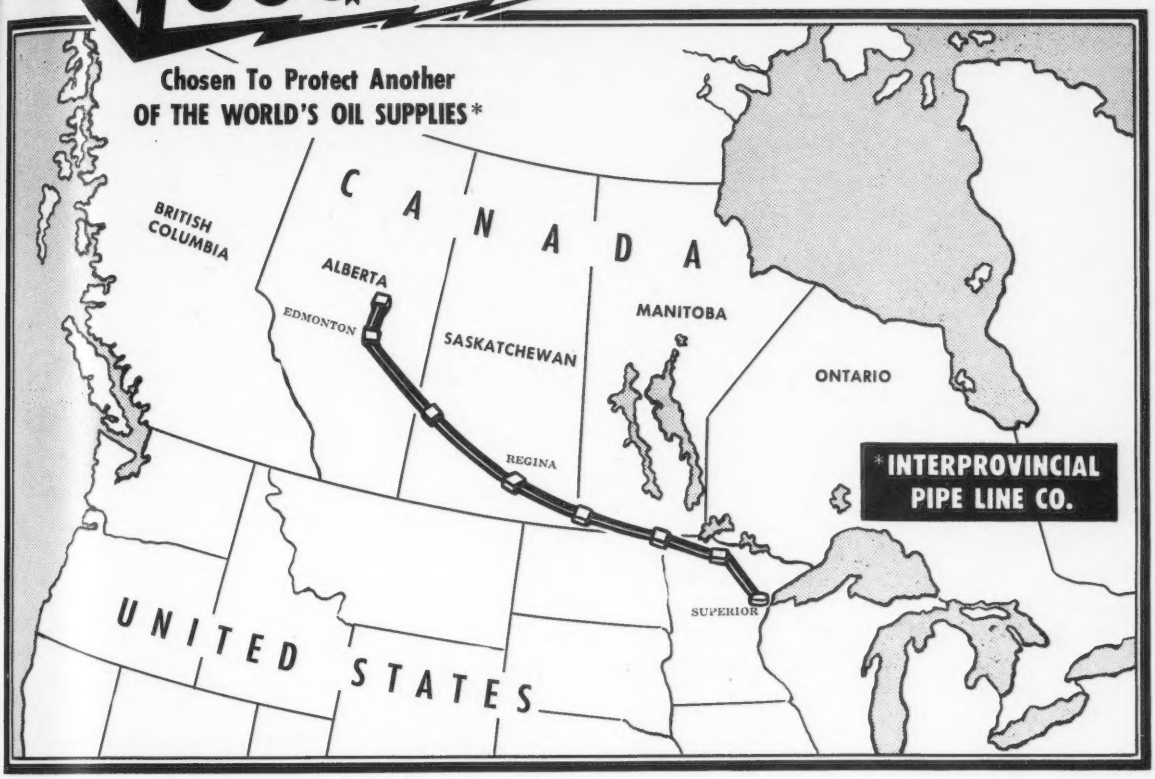


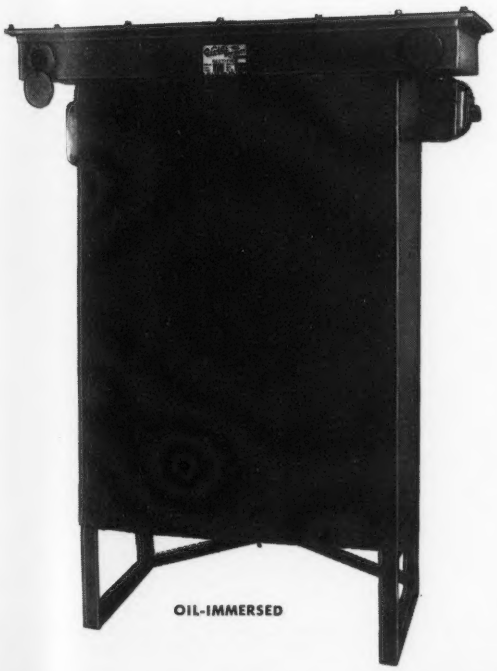


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**Report of the Correlating Committee on Cathodic Protection. Bulletins I, II, III, IV. Per Copy, postpaid** ..... $ .50

## TECHNICAL REPORTS

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**Acme-Fisher Division,** Broadway Rubber Corp., 529 East Broadway, Louisville 2, Ky., and Acme-Fisher of Texas, Inc., P. O. Box 15066, Houston 20, Texas offer a 14-page brochure to those interested in the use of linings for the prevention of corrosion.

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**Prufcoat Laboratories, Inc.,** 50 East 42nd St., New York 17, N. Y. offers Prufcoat Technical Bulletin No. 501 showing in chart form the chemical resistance of various types of Prufcoat. Potential users are provided with the resistance ratings of the several products of the company to 69 corrosive chemicals in concentrated and dilute solutions.

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**Lead** has been relieved of all government restrictions Lead Industries Association has announced.

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**UAP Wills** Metallic O-rings, permanent easily installed hollow metal tubing filled with inert gas at 600 psi are being manufactured by United Aircraft Products, Inc., Dayton, Ohio. The rings offer positive metal to metal static seals wherever problems of heat, pressure, corrosive liquids or gases are involved. They may be installed in present ring grooves and are rated as high as 20,000 psi at temperatures limited only by the characteristics of the metals from which they are made. Re-use without loss of a perfect seal if the ring is not damaged is claimed. UAP Technical Bulletin No. 21252 gives full data and may be obtained on request.

•

**Polyethylene** beakers molded in one piece with a pouring spout, similar in design to glass beakers are available from American Agile Corp., Maple Heights, Ohio in 250 ml and 400 ml sizes. The beakers besides having greater impact strength than glass or ceramic vessels are resistant to most mineral acids including hydrofluoric acid and its mixtures, alkalies and many chemicals between —20 degrees and +150 degrees F.

•

**Bettinger Corp.,** Waltham, Mass., has been awarded a $200,000 contract for the ceramic coating of nozzle boxes for turbo superchargers by Heinz Manufacturing Co. The coatings are a mixture of grit and various types of clay and metal oxides, refractorizing agents and water. Parts are prepared by hot acid solutions followed by sandblasting after which they are dipped or sprayed with a solution and fired at temperatures up to 1875 degrees F. The resulting coating often is only .001-inch thick. Wide domestic application of the coatings is foreseen by Bettinger Corp.

**Yardley Plastics Co.,** Columbus, Ohio, supplied 6-inch plastic pipe used by Timken Roller Bearing Co. at Columbus to case return wells of the plant's cooling water system to a depth of 475 feet packed off at the 400-foot level, forcing return water into strata below the source of supply.

•

**Carpenter Steel Co.,** Reading, Pa., has issued a revised 4-color segregation chart used for quick identification of stainless steels. The chart will be useful in separating stainless steel scrap for salvage and prove helpful in identifying mixed stocks. The chart diagrams stainless type numbers and describes how to use each of eleven different tests for the nitric acid, muriatic acid, magnet, spark, hardness, sulfur spot, nickel spot and stabilization tests. Preparation of samples is described. A copy of the 11 x 22 inch chart can be obtained by writing to the company's 372 West Bern Street offices at Reading.

•

**Haynes-Stellite Co.,** 30 East 42nd St., New York 17, N. Y. offers on request a new 24-page booklet "Long-Wearing Machinery Parts," which describes a wide variety of cast and wrought alloy parts now being used to solve abrasion, corrosion and high-temperature problems. More than 60 blueprints, tables and photographs are used. Information forms included in the booklet may be used by those who have experienced repeated failure of a machinery part to help solve their problem by assuring that the right alloy is recommended for the job.

•

**Tygorust,** a new primer designed by United States Stoneware Company, Akron 9, Ohio to be used on wet or dry rusted steel, wood or concrete for bonding vinyls to practically any previously painted surface requires a minimum of surface preparation. Trial quantities of the new material may be obtained from the company.

•

**Bondwell, Inc.,** 1401 Middle Harbor Road, Oakland, Calif., is the new corporate name adopted by the C. E. Freeman Company organization.

•

**Rustclean,** a chemical treatment developed by Octagon Process, Inc., 15 Bank St., Staten Island 1, New York, is said by the manufacturers to remove rust, tarnish and light oil, chemically prepare metal for paint and retard corrosion. The material cleans the surface of steel, iron, aluminum, zinc and cadmium and forms a phosphate coating as a base for organic finishes. It also removes tarnish from copper and copper alloys. Several types of Rustclean are available, each designed for different work.

## PERSONALS

**William A. Fitzgerald** has been named assistant sales manager for Ajax Metal Division, H. Kramer & Co., Philadelphia, Pa.

•

**Robert D. deLaski** has been appointed Northeastern representative of the Pittsburgh Coke and Chemical Company's coating division with offices in the Empire State Building, New York.

•

**Leon F. Miller** has been elected vice president in charge of sales and engineering of the Machine Division of The Osborn Manufacturing Co., Cleveland.

•

**R. W. Stetson** has joined the Cathodic Protection Sales Group of Dow Chemical Company's magnesium department. He is a specialist in marine engineering. Holding a commander's commission in the U. S. Maritime Service, he has been project engineer for the application of magnesium anodes on the Marine Chemist, a sea-going chemical transport leased by Dow Chemical Company. The vessel is the first large active commercial vessel using magnesium for protection of its hull against corrosion.

•

**James I. Hoffman,** chief of the surface chemistry section of the National Bureau of Standards, has been appointed assistant chief of the chemistry division.

•

**Henry P. Berry** has been named Southern Regional manager for Insul-Mastic Corporation of America. Mr. Berry formerly was assistant to the chief insulation engineer of Carbide and Carbon Chemicals Corp.

•

**William P. Simmons** has been named sales representative in its western territory by Alloy Steel Products Co., Inc. He will cooperate closely with Republic Supply Co. of California, authorized distributor for the company's Aloyco valves. His headquarters will be 24 California St., San Francisco, Cal.

•

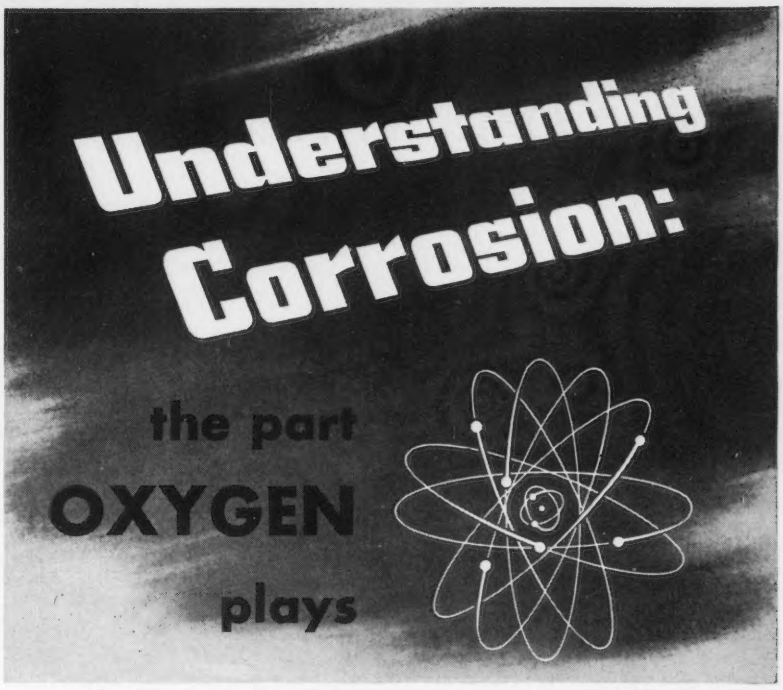
**Robert W. Ellms** has been promoted to assistant chief engineer and **Ted Hatch** has been named supervisor, research and development dept., Machine Division, Osborn Manufacturing Co., Cleveland, Ohio.

•

**Martin E. Gilwood** has been made Director of Research, The Permutit Company, New York, N. Y. A Rensselaer Polytechnic Institute graduate, he will be responsible for research, analytical and pilot plant laboratories at Birmingham, N. J. and market research activities in New York.

•

**Raymond J. Lawn** has been made supervisor of synthetic coatings research by Pittsburgh Coke & Chemical Co., Pittsburgh, Pa. He will be responsible for the supervision and coordination of the company's research and development activities as well as laboratory technical service on synthetic corrosion resistant industrial coatings. He formerly was engaged in coatings and research development with United States Wallpaper Corp. and with Plaskon Div., Johns-Manville Corp.




Whether corrosion of metal occurs in moist atmosphere, under water, under ground, or in salt, alkali, or mineral acid solutions, the presence of oxygen is generally the controlling factor. The rate of corrosion depends mainly upon the concentration of available oxygen at the surface of the metal, but is influenced by such factors as temperature, pH, fluid velocity, viscosity, exposed surface area, pressure and humidity of the air, the depth to which the metal is immersed, and the presence of galvanic or other electrical actions.

In air, for example, the humidity becomes a determinant at about 35% and causes a marked increase in corrosion when it exceeds a critical point at 65%. If even minute quantities of corrosive gases are also present, the rate of attack on the metal is further accelerated. In liquid, the rate at which oxygen reaches a metal surface is governed by the velocity of the liquid. In a quiet system with velocity at a minimum, transfer of oxygen to metal is slow and by a diffusion process. Increased velocities increase the rate at which oxygen is brought in contact with the metal and, in turn, increases the rate of metal deterioration.

Getting at the root of corrosion's cause through understanding of the complex factors involved is a first step in control. Some of those factors can be eliminated or regulated. Helping metal get on with those that cannot has long been our specialized field of activity.

Dampney equipment-engineered protective coatings — vinyls, silicones, chlorinated rubber, ceramics, asphaltums — have provided a practical approach to many a difficult corrosion problem. Let us apply that experience to your particular corrosion control needs.

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THE DAMPNEY COMPANY

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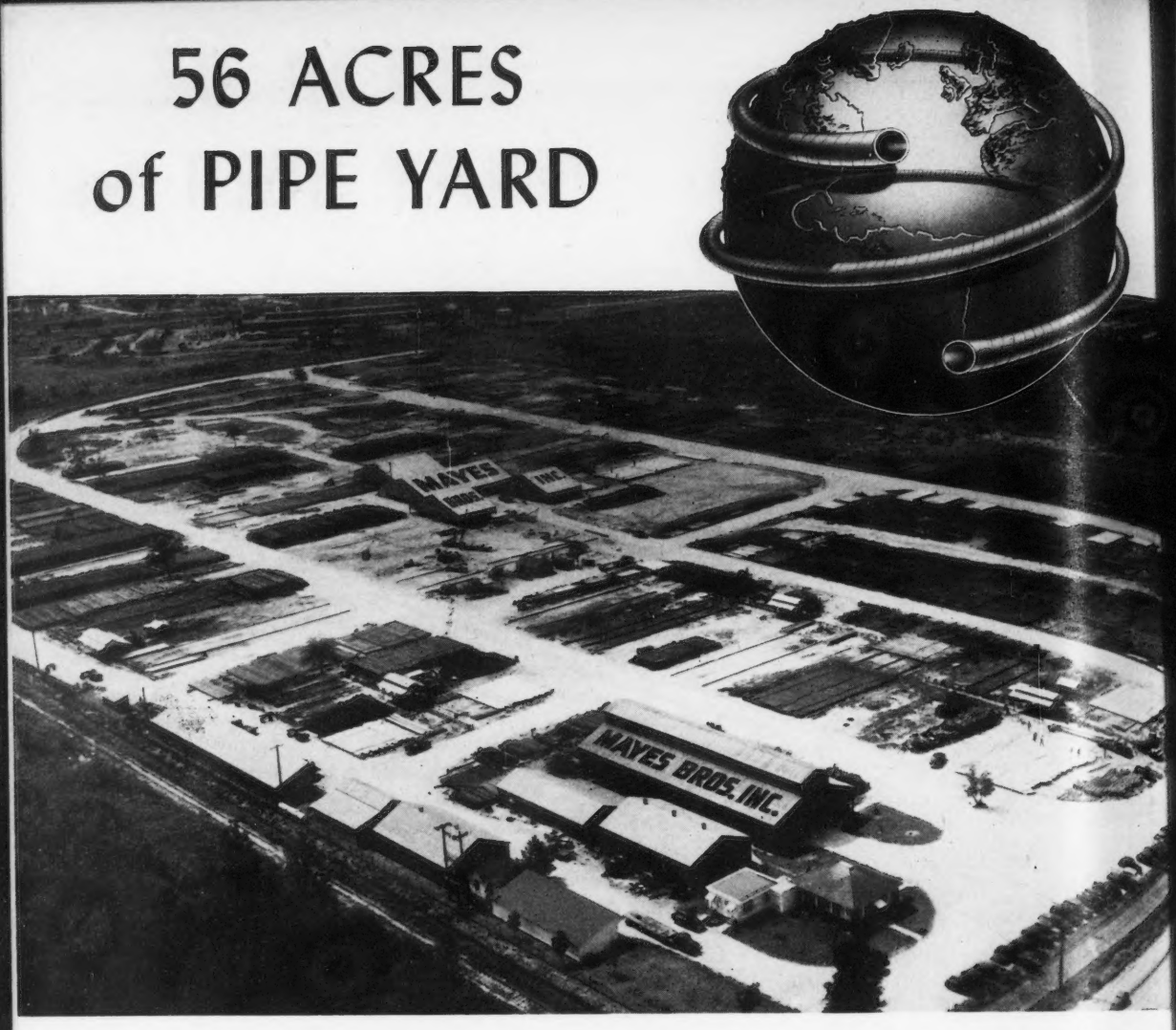
# 56 ACRES of PIPE YARD

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Our modern plant and equipment, manned by the top hands in the business, is prepared to handle both your new and used pipe jobs, no matter how large or small. Complete reconditioning facilities available.

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HOUSTON

# More Than 1360 Register for Galveston Meeting

N. E. Berry and Mars G. Fontana, retiring and new presidents of NACE, are shown at the ceremony at Galveston when they received certificates as "Temporary Texans." The officers also were given ten gallon hats by exhibitors at the Fellowship Hour and Barbecue. On the extreme left is W. H. Stewart, and on the extreme right W. F. Oxford, Jr., both of Sun Oil Co., Beaumont, Texas, and respectively co-chairman and chairman of the entertainment committee.

A driving squall that brought a downpour of rain at Galveston in the early hours of Monday, March 10, only temporarily dampened the spirits of the early arrivals for the NACE Eighth Annual Conference and Exhibition. The rain stopped and a bright sun came out during the afternoon. While some travel difficulty was reported as a result of bad flying weather and the railway strike that affected St. Louis and lines coming through it total registration at the conference was 1360.

Registration was heavy Monday morning, slacked off during the afternoon and then resumed full blast at all three booths Tuesday morning. Early crowds attended the exhibit on the Galveston Pleasure Pier during the morning Tuesday and the annual general business meeting of the association was well attended.

### Picture Shown First Time

The International Nickel Co. sound and color motion picture "Corrosion in Action," was shown during Tuesday afternoon and a spirited discussion followed under the guidance of F. L. LaQue, head of Inco's corrosion engineering section.

### Sessions Well Attended

Wednesday sessions were exceptionally well attended. The Snack Bar room frequently was taxed to capacity and while the Marine Room was never completely filled, substantial numbers were present to attend the presentation of papers and ask questions.

Attendance was especially heavy at the presentation of paper number 14 by Robert P. Pierce of Pennsylvania Salt Manufacturing Co., Philadelphia, Pa. titled "Economics of Industrial Maintenance Painting."

### Round Tables Crowded

Exceptionally good attendance was noted at the Pipe Line Corrosion round table Friday morning at the Buccaneer and the General Corrosion Problems round table session was held at the Marine Room. These two sessions, as usual, attracted the largest groups at technical sessions during the conference.

## *Board Decisions Pertain Principally to Internal Functions of the Association*

Decisions at meetings of the outgoing and new boards of directors of the National Association of Corrosion Engineers held at Galveston during the Eight Annual Conference and exhibition pertained principally to matters affecting the internal organization of the association. Three decisions affecting sections and their functions were made. These were:

1. Section by-laws will be studied to determine their degree of conformity with association by-laws. Information derived will be used in preparing suggestions for new sections preparing by-laws.

2. Authorized annual payment of $100 to sections with a roster of over 100 members in good standing instead of the $50 previously authorized.

3. Adopted a revised wording for the charter for sections. The printed charters are to be signed by appropriate officials and sent to each section.

### Awards and Research

A plan was approved for passing on recommendations for future sponsored research projects. The proposal includes preparation of a prospectus and the procedure for obtaining final approval and raising necessary funds.

Continuing research under way under the supervision of Technical Practices Sub-Committee 1G on Sulfide Stress Corrosion was approved. Details of raising necessary additional funds will be worked out later.

A proposal whereby the association would offer an annual award of $50 for

(Continued on Page 12)

## "Temporary Texan" Certificates Awarded

Certificates as "Temporary Texans" and ten gallon hats were given retiring NACE President N. E. Berry and incoming President Mars G. Fontana at a presentation ceremony during the Fellowship Hour and Barbecue at Galveston Pleasure Pier Tuesday, March 11 during the 1952 conference. The event, annually sponsored by the exhibitors at the conference, was attended by about 1600, believed the largest attendance at a similar NACE function.

Liberal praise to Jack Harris, exhibits chairman and the members of his committee responsible for the evening's events was voiced by many.

Entertainment by a girl band was enjoyed, and impromptu piano music featured the latter part of the evening during which there was some dancing. The barbecue was expertly and quickly served.

## Ladies Entertained With Full Program

A program of entertainment for ladies attending the conference included a trip to the San Jacinto Monument, site of the deciding battle of the war in which Texas won its independence from Mexico, and an afternoon tea and style show at the Galvez Hotel. A large number of ladies attended these events and the Fellowship Hour and Barbecue and the annual banquet.

## *New Directors Take Office at Meeting*

Hugh P. Godard, Aluminum Laboratories, Ltd., Kingston Ontario, Canada and V. V. Kendall, National Tube Company, Pittsburgh, Pa. are new directors representing corporate membership effective with the last day of the Galveston Conference. Norman Hackerman, University of Texas, Austin, becomes new director representing active membership.

L. L. Whiteneck, Board of Harbor Commissioners, Long Beach, Cal. is the new director representing Western Region of the association.

**REPORT ON THE EIGHTH ANNUAL CONFERENCE AND EXHIBITION AT GALVESTON**

# 1952 NACE Awards Given at Banquet

President N. E. Berry made the 1952 annual NACE awards during the Galveston Conference during the banquet held at the Marine Room on Galveston Pleasure Pier. Starr Thayer, Houston consulting engineer, and among the first in the Southwest to apply cathodic protection to underground pipe lines, received the Frank Newman Speller Award for achievement in corrosion engineering.

R. W. Auxier, manager of the Chemical Department, Research Laboratory, Westinghouse Electric Corp., East Pittsburgh, Pa. acted as proxy for Earl A. Gulbransen in receiving the Willis Rodney Whitney Award for achievement in the field of corrosion science. Mr. Gulbransen is absent in England.

## 400 See Inco Movie

An audience of about 400 witnessed the premiere showing of the International Nickel Company's motion picture "Corrosion in Action," the opening event on the technical program at the Galveston meeting Tuesday, March 11. The audience reaction was that the picture should be shown again during the conference.

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1210 HAYS STREET, HOUSTON, TEXAS

**Nearly 1500 persons were served at these food lines at the annual Fellowship Hour and Barbecue on the Galveston Pleasure Pier March 11. The event, sponsored by the exhibitors, had an estimated attendance of 1750, considered to be the largest at any equivalent affair given by the association.**

## Exhibitors Pleased With 8th Conference

Exhibitors at the 1952 NACE Conference Exhibition at Galveston March 10-14 were well pleased with the meeting. Jack Harris, conference exhibits chairman reported. The annual exhibitors' meeting held to get a concensus and receive suggestions for improvement was characterized by expressions of general approval from exhibitors, Mr. Harris reported.

Arrangement of the exhibit hall was particularly agreeable to the companies with materials on display. Although at times heavy attendance at the simultaneous technical sessions drained traffic from the exhibit area, most were pleased with the results gained.

## Godard and Wick Take Inter-Society Committee Offices

H. P. Godard, of Aluminium Laboratories, Ltd., Kingston, Ontario assumed the chairmanship of the Inter-Society Corrosion Committee at its meeting at Galveston during the Eighth Annual Conference and Exhibition. He succeeds Sam Tour of New York City. I. M. Wick of Bethlehem Steel Co., Bethlehem, Pa., became vice-chairman.

Minutes of the meeting, now being transcribed at Central Office NACE will be the basis for a news story in the May issue of Corrosion. Articles of organization of the society also are scheduled to be run.

•

In 1952 over 52,000 copies of reprints of material from Corrosion were reprinted.

## Board Decisions—

(Continued from Page 11)

a paper prepared on a corrosion subject by a student was taken under advisement.

### Other Decisions Made

The board also took two actions respecting the association's publications. A resolution submitted to the board by the publication committee broadening the definition of corrosion applying to decisions by the committee was approved. The committee is concerned with publication of articles dealing with deterioration of materials other than metal, especially concrete used for marine structures.

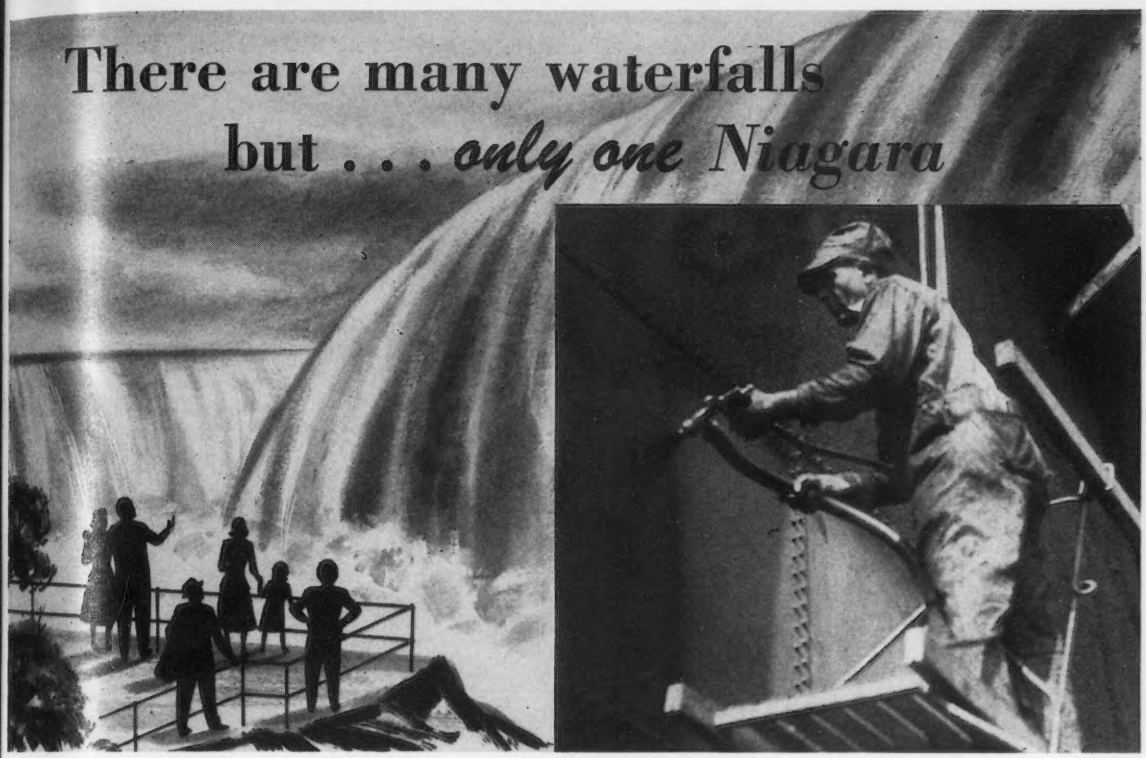
An increase in the advertising rates of Corrosion was approved, effective January 1, 1953.

The Correlating Committee on Cathodic Protection, which recently has completed its final report on its initial objectives, was asked by the board to continue its organization in the belief that further problems interesting to the committee members will require study in the future.

A contribution of $100 for 1952 to the Steel Structures Painting Council was approved.

## Plans for Chicago Meeting in '53 Made

Executive Secretary A. B. Campbell scheduled a meeting at Chicago late in March to discuss plans for the 1953 conference to be held there. Work on both the technical program and the exhibition will get under way soon, Mr. Campbell said.




# There are many coatings but . . . *only one* INSUL-MASTIC

INSUL-MASTIC pioneered heavy coatings—of *superior* quality. Years of thorough testing and experimentation, by corrosion plagued chemical companies, proved conclusively that long term protection against acids, alkalis and weather was at long last possible, through the use of INSUL-MASTIC.

The government confirmed this finding—INSUL-MASTIC being the only mastic coating ever approved under the original rigid specification for "mothballing" the war materiel.

INSUL-MASTIC *superior* coatings brought about changes in coating specifications throughout industry. The extremely long life and very low moisture vapor penetration rate of INSUL-MASTIC were the qualities that industry was seeking in its fight against corrosion and moisture penetration. The proven formulae which brought this enduring protection are patented and *cannot be duplicated* . . . there is only *one* INSUL-MASTIC.

Tests by the National Bureau of Standards and other impartial laboratories* prove the value of INSUL-MASTIC's basic ingredients for increasing coating life. Those ingredients are a maximum percentage of Gilsonite and *carefully* chosen mica and asbestos.

INSUL-MASTIC Vaporseal Coatings will prevent corrosion under severe chemical conditions, and will vaporseal insulation or building walls.

INSUL-MASTIC Type "D" Insulation will control condensation or prevent 65% of heat loss.

There is only *one* INSUL-MASTIC—Write for the name of our nearest licensee.

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* *Names on request*

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## REPORT ON THE EIGHTH ANNUAL CONFERENCE AND EXHIBITION AT GALVESTON

# Watkins Named New Chairman of TP-9

Franklin M. Watkins, Sinclair Research Laboratories, Harvey, Ill., for the past year vice-chairman of Technical Practices Committee 9 on Corrosion Inhibitors is new chairman of the committee, effective with the Galveston conference. Aaron Wachter, Shell Development Co., Emeryville, Cal. becomes past-president.

The committee discussed an important research subject in the fundamental science of inhibition with the view of soliciting financial support for it from Industry.

Contributions on corrosion inhibitors received by the committee during the year also were discussed.

## Bilhartz Takes Over As TP-1 Chairman

H. L. Bilhartz of Atlantic Refining Co., Dallas, took over the chairmanship of Technical Practices Committee 1 Corrosion of Oil and Gas Well Equipment Monday, March 10, at the conclusion of a meeting of the committee at the Buccaneer Hotel, Galveston. R. C. Buchan, Humble Oil and Refining Co., Houston, became vice chairman.

During the day-long committee meeting reports were heard from TP-1B and TP-1D. TP-1H, formed recently at Fort Worth, also gave a report.

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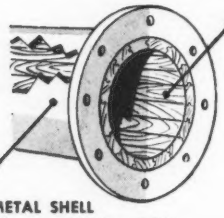
INNER WOOD LINING
*internal diameters from 4" to 40"*



OUTER METAL SHELL
*wall thicknesses 5/64" to 1/4"*

Ideal for corrosive liquids and gases including process waters, industrial waste liquors, acid, alkali and salt solutions, chemical gases, pulps and slurries. For catalog and additional information, write Dept. C

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Bay City • Michigan

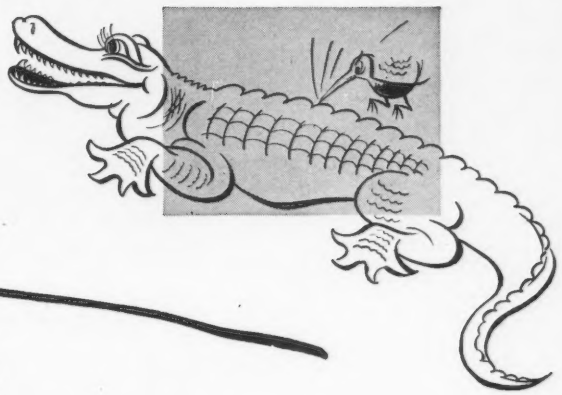
Well-attended meetings of Technical Practices Committee 1 on Corrosion of Oil and Gas Well Equipment were held at Galveston during the Eighth Annual Conference.

Walter P. Noser, of Humble Pipe Line Co., Houston, chairman, presides at a meeting of Technical Practices Committee 2 on Galvanic Anodes for Cathodic Protection held at the Buccaneer Hotel, Galveston, during the annual Conference.

Members of Technical Practices Committee 9 on Corrosion Inhibitors at its meeting at the Buccaneer Hotel, Galveston, during the 1952 conference.

TP-12 on the Effect of Electrical Grounding on Corrosion met during the Galveston Conference. Irwin M. Dietze, of the Department of Water and Power, City of Los Angeles, is standing.

*Like the 'Gator's tough skin that shields what's within . . .*



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Johns-Manville Asbestos Pipeline Felt—*the only type of wrapper that has survived more than 50 years of service in all types of soil*—now protects more than 100,000 miles of oil and gas pipelines!

A sturdy, inorganic product, Johns-Manville Asbestos Felt resists rot and decay, stands up in both acid and alkali soils. It has the thickness and toughness needed to shield pipeline enamels from earth load and soil stresses. And it permits the protective enamel coating to properly function against corrosion.

Johns-Manville Asbestos Felt is flexible; wraps easily without cracking. It guards enamel from impact damage both during installation of field-wrapped pipe, and during transportation and installation of mill-wrapped pipe.

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# REPORT ON THE EIGHTH ANNUAL CONFERENCE AND EXHIBITION AT GALVESTON

## TP-16 Meeting Lasts Day and Half at Annual Conference

Extensive discussions of returns from a questionnaire sent out by TP-16A on Stray Railway Current Electrolysis featured the meeting of Technical Practices Committee 16 on Electrolysis and Corrosion of Cable Sheaths at Galveston during the annual conference. The whole committee and its six subcommittees were in session all day March 10 and during the morning of March 12. Thirty-five members attended.

TP-16E on Corrosion Protection of Pipe Type Cables presented a proposed questionnaire. The questionnaire, after general discussion, was revised to be mailed to those interested in this kind of cable. Results of all surveys by the committee are being collected with the view of publishing a manual on "Electrolysis and Cable Sheath Corrosion."

TP-16F on Non-Metallic Sheaths and Coatings initiated a program to test effectiveness of protective covers over metallic sheaths of lead and aluminum.

"The lively and effective discussion during the committee meetings is the best opportunity for instruction," Irwin C. Dietze, chairman, said. "All subcommittees have a good program lined up for next year which will be reported to all committee members in minutes," he said.

Technical Practices Committee 16 on Electrolysis and Corrosion of Cable Sheaths and its six subcommittees met all day March 10 and half a day March 12 during the Galveston Conference.

Technical Practices Committee 19 on Corrosion by De-Icing Salts held its first meeting at a NACE conference at Galveston during the annual conference there. This committee, organized in 1951, has wide representation among groups interested in preventing corrosion losses from salt used to melt ice on streets.

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Strapping designed to last the lifetime of the insulation.

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SM-3

## Nine TP Meetings Held During March 11

Nine meetings of Technical Practices Committees were held during Tuesday. TP-6B had an attendance of 15, TP-6E of 15, while 25 were present for the meeting of TP-18 at which two additional sub-committees were proposed.

TP-17 had an attendance of 40, while 50 to 75 were present during the meeting of TP-1G. TP-4, 5C, 7, 8 and 12 also scheduled meetings.

## Oil String Casing Corrosion Group Has Meeting at Galveston

A meeting of TP-1H on Corrosion of Oil String Casing was held Thursday, March 13 at the Buccaneer Hotel, Galveston, Texas. This subcommittee of TP-1 has Jack L. Battle, Humble Oil and Refining Co., Houston, as chairman and fifteen members.

## Robinson Is Elected TP-2 Vice-Chairman

H. A. Robinson of Dow Chemical Company, Midland, Michigan was elected vice-chairman of Technical Practices Committee 2 on Galvanic Anodes for Cathodic Protection at the meeting of the Committee at the NACE 1952 Annual Conference in Galveston.

## *Committee Directory To Be Expanded*

Standing and other committees of NACE will be included in the next publication of a committee directory of members of technical practices committees, the association's board of directors decided at its Galveston conference meetings. The new publication, currently issued in July yearly, will have a changed title reflecting its changed content.

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In December the association provides in Corrosion a cross-indexed table listing all technical material printed during the year.

## REPORT ON THE EIGHTH ANNUAL CONFERENCE AND EXHIBITION AT GALVESTON

### LaQue Gives Review Of Work Done by Publication Committee

By F. L. LaQUE, Chairman

The writer took over the chairmanship of the Publication Committee from Dr. Ivy Parker in March, 1951. The work of this committee has continued with the great benefit of the momentum it had when Dr. Parker relinquished the chairmanship. Fortunately, the former members of the committee and the chairmen of the sub-committees continued to function and it has been due largely to their efforts, as well as those of Dr. Parker as editor of Corrosion, and N. E. Hamner as managing editor, that we are able to report a very successful year for this committee.

One of the major functions of the NACE is to disseminate information on corrosion and its control. This it accomplishes primarily through Corrosion magazine. It costs a good deal to publish a magazine of the caliber of Corrosion and to undertake the many other publication activities of the association. In 1951 this amounted to over $98,000. Fortunately, through the efforts of Mr. Hamner, supported by many members, the loyalty of our old advertisers and the increasing appeal of Corrosion as an advertising medium (total circulation increased 22 per cent to 4281 copies per issue), we are able to report an excess of income over expenditure for publications of about $4100. Gross advertising revenue was up about $10,000 to $67,000. The corresponding estimate for 1952 is $70,000. While the primary objective of our publication activities is not to earn money, it is gratifying that we have been able to accomplish our major purposes without expense to the association.

We have increased the amount of technical material published in pace with the increased number of advertising pages. Total editorial pages in 1951 were 841—an increase of 77.

We believe also that through the diligent efforts of the Editorial Review Committee under the chairmanship of F. N. Alquist, we have improved the quality of the technical papers we have published. The chairman joins Mr. Alquist in thanking the many members in addition to those serving directly on the review committee who assisted in reviewing papers for publication.

A very gratifying development has been the increase in the number of papers that have been submitted voluntarily. Much of this has resulted from the cooperation of the local sections. We would like to see even more of this and we hope that the local section officers will continue to assist us by placing copies of the Guide to Authors (prepared by Mr. E. R. Stauffacher and his committee) in the hands of all who may be in a position to contribute to our editorial pages. We woud like to impress on all members the desirability of attaching greater value to their work in this field by publication of the results of their efforts in our magazine.

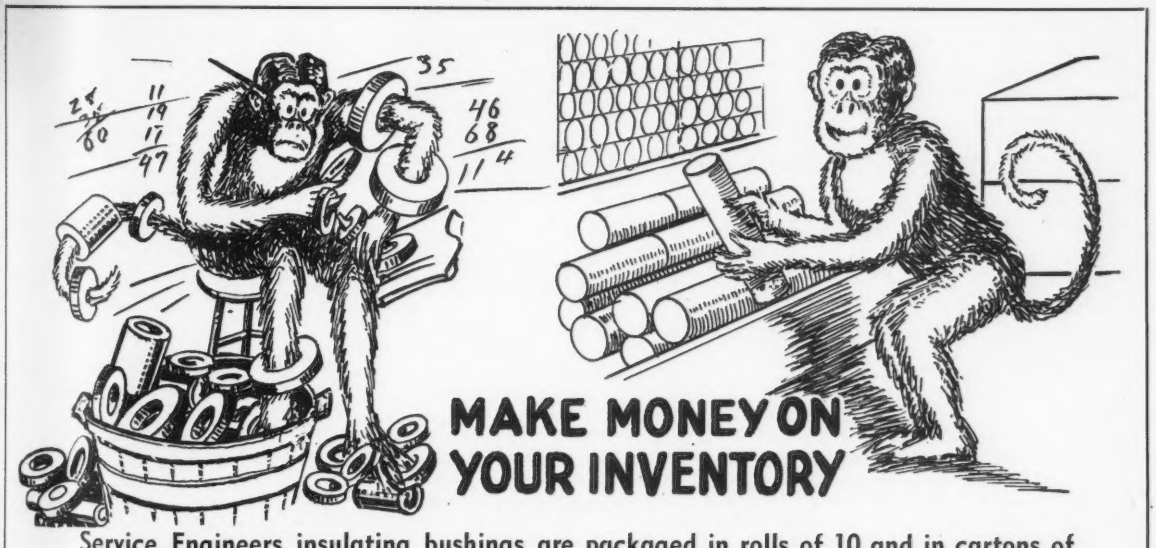
Through the strenuous efforts of Miss Bebbington, as chairman, and the members of the Abstract Committee, plus the working out of the difficult mechanical details by the staff at headquarters, we were able in 1951 to initiate the Abstract Card Service. We now have 94 subscribers at $75 each and should acquire at least 15 more in 1952. With this number, the project should be practically self sustaining.

Another major effort was the publication of the 1946-47 Corrosion Bibliography. This is the second in a continuing series which will become more popular as it grows.

The principal miscellaneous publications were:

1. A revised membership brochure.
2. The guide to the NACE Abstract Service.
3. The Guide for Preparation and Presentation of Papers.
4. The complete report of the Correlating Committee on Cathodic Protection—this has been so well received that it has gone into its second printing.

In closing, we venture to predict that with a continuation of the hard work by the several members of the Committee, the energy and efficiency of Mr. Hamner and his staff in Houston, and the continued interest and cooperation by all you members, we will be able to report in 1953 an even better record of accomplishments by your Publication Committee.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## REPORT ON THE EIGHTH ANNUAL CONFERENCE AND EXHIBITION AT GALVESTON

### Broader Definition Of Corrosion Is Asked by Committee

The Publication Committee has asked the NACE Board of Directors to consider adoption by the association of a broader definition of corrosion than that which heretofore has guided the determinations of the committee in its approval of technical material. Specifically, the question pertains to a paper involving the deterioration of concrete in salt water recently offered the association for publication. The committee felt the material in this paper and perhaps in other papers devoted to deterioration of shore and offshore structures in salt water properly can be considered interesting to the corrosion engineer on the same basis as other alternatives to metal construction now are considered. This decision was one of several reached at a March 10 meeting of the committee held at the Buccaneer Hotel during the Eighth Annual Conference at Galveston.

The meeting also marked the last official appearance of F. L. LaQue of The International Nickel Co., Inc., as chairman of the committee.

The committee agreed to sugest again to the association's board of directors, as had been done in 1951, that separate publication of the membership directory be reconsidered. It was advocated that the board consider publishing a year book which would include the directory, the articles of organization and by-laws and the Directory of Technical Practices Committee members.

The committee suggested the increasing cost should not be carried by Corrosion but that some way be found to make the membership directory more or less self-supporting.

#### Advertising Rates Increased

Mr. LaQue reported the association's board of directors at a March 9 meeting approved increasing the advertising rates of Corrosion magazine but asked for additional supporting data on a contention the price of the publication to subscribers be increased. The managing editor was instructed to prepare data showing average cost and incremental costs per copy for further consideration by the publication committee.

The committee did, however, recommend an increase in the price of Corrosion to $10 for foreign subscribers outside of North America be approved by the board to offset partially the difficulties incident to serving this class of subscribers.

#### "Corrosion Problems" Discussed

In view of the extreme difficulty experienced in securing the necessary answers to continue the "Corrosion Problems" column in Corrosion, the committee recommended that Mr. E. A. Tice be requested to advise the committee on the advisability of discontinuing it. Furthermore, the committee proposed, that if the column is discontinued that an effort be made to notify each person who has submitted a question not answered that the column had been discontinued and that no answer had been received to his question.

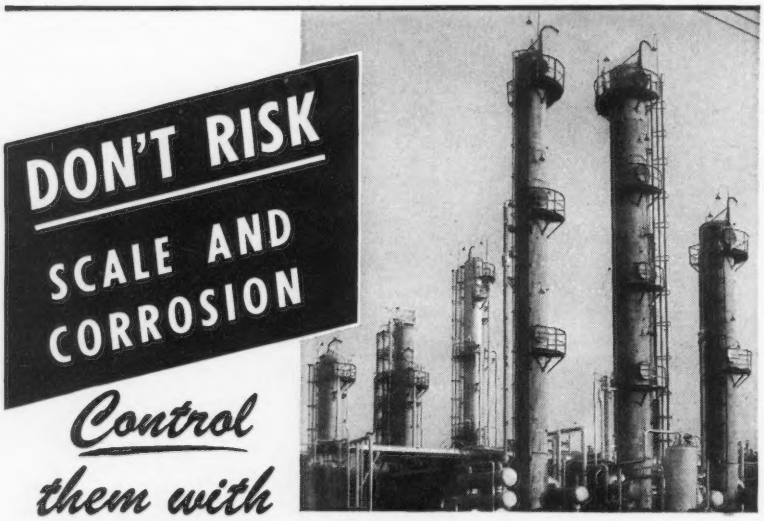
The committee also set up machinery whereby the status of all technical manuscripts under review for six months will automatically be reported to authors.

E. R. Stauffacher, chairman of the rules subcommittee was requested to keep his committee on a stand-by basis so that suggestions for additions to or changes in the recently approved Rules for the Preparation and Presentation of Papers might be collected and considered. The rules are expected to be published in final form soon.

### More Papers Are To Be Sought by NACE

Means of getting more papers submitted for publication in Corrosion magazine were discussed at a meeting of the NACE Editorial Review Committee March 11 at the Buccaneer Hotel during the Galveston Conference. The committee, functioning for the last time under retiring chairman F. N. Alquist, also made several decisions on procedural matters with respect to reviewing papers and also planned to submit lists of names of persons proposed as possible new members of the committee.

The work of the committee since its last meeting in New York in 1951 was reviewed briefly. New Chairman George Diehlman assumed control of the committee and retiring chairman Alquest agreed to continue working with the group as a member for another year. The addition of a sixth committee member is being considered.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# More Subscribers For Abstract Card Service Are Sought

The NACE Abstract Committee, meeting under chairmanship of Miss Marguerite Bebbington March 11 discussed means whereby additional subscribers to the association's abstract punch card service can be secured, weighed and decided numerous problems relative to the index. A recommendation was prepared for the Publication Committee on the base number of subscriptions for 1952 cards by new subscribers that will be necessary before these cards can be reprinted.

Mrs. Claudia Hayward, of Central Office Staff, who is in charge of preparing and issuing the cards, told the committee about some of her problems.

In general, the committee was pleased with the manner in which the cards are being issued, and with the number of subscribers secured. It was felt, however, that additional subscribers were needed and that the possibilities for securing new subscribers have by no means been fully explored by NACE.

## Correspondents Meet

Correspondents of Corrosion Magazine met at the Buccaneer Hotel, Galveston during the annual conference. A scheme whereby three members of the group will be retired each year was proposed, and lists of suggested replacements were solicited from retiring members, those who have longest service as correspondents.

•

Nearly all technical papers presented at annual meetings of NACE are published in Corrosion after review by the Editorial Review Committee of the association.


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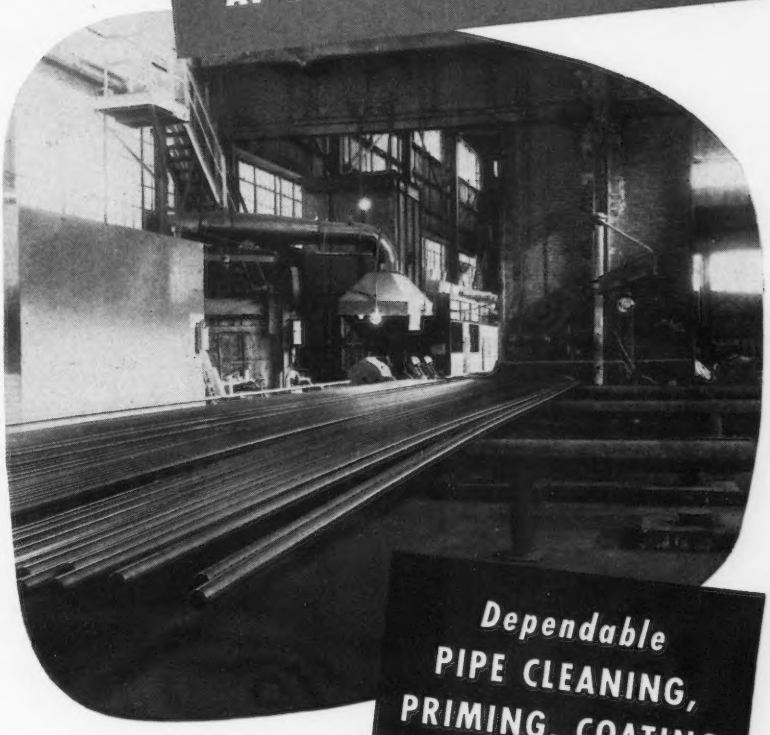

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Vol. 8

# Corrosion Abstracts

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## 1. GENERAL

### 1.1 Miscellaneous

1.1

**Progress in Industry Awaits Many Developments in Engineering Materials.** T. C. Du Mond. *Materials & Methods*, 33, 57-61 (1951) Jan.

Discusses needs of industry for materials of better resistance to corrosion and to high temperatures, also other miscellaneous requirements. Emphasizes need for more basic research.—BLR.

1.1

**Some Aspects of the Protection of Iron and Steel Against Corrosion.** U. R. Evans. *J. Oil Colour Chemists Assoc.*, 33, No. 364, 452-458 (1950) Oct.

The author discussed the following topics in this lecture, presented at Hull in April 1950: high temperature oxidation; corrosion of ferrous metals by water and oxygen; corrosion by salt solutions and oxygen; corrosion inhibition by metallic soaps; surface preparation before painting, including the use of zinc coatings; and the use of paints containing metallic zinc. He described various types of zinc dust paints utilizing chlorinated rubber or polystyrene vehicles, and cementiferous paints which have been developed in the laboratory. Such paints will provide sacrificial protection of the underlying ferrous metal if they contain 95 percent of metallic zinc by weight.—ZDA.

1.1

**How to Find Detailed Information When You Want It.** A. H. Geisler. GE


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## CODE OF AGENCIES SUPPLYING CORROSION ABSTRACTS

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial Institute Library. 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana. Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

Res. Lab. *Metal Progress*, **57**, No. 5, 613-617 (1950) May.

A brief description is presented of a new system of filing literature abstracts of a metallurgical nature for ready reference. This method consists of a punch-card filing system. The one attractive feature of the punch-card system for filing literature abstracts is that the reference can be coded in a number of ways to accomplish an interrelation of ideas without requiring duplicate cards. The cards can then be sorted in any one of these ways to obtain the desired information. The literature can be logically and completely classified in one of the following four ways: index of processes and properties; materials index; common variable index; or the author index.—TDD.

1.1

**Corrosion and Its Prevention.** H. B. FOOTNER. *Brit. Petroleum Equipment News*, **1**, No. 6, 18-21 (1950).

Deals essentially with corrosion of steelwork under naturally occurring conditions, and means for its prevention and reviews causes of corrosion which may be present in air, water or soil and principles applicable for prevention (protective coatings, organic and metallic, use of inhibitors and cathodic protection).—INCO.

1.1

**Little Known Russian Works on Metal Corrosion.** (In Russian.) S. A. BALEZIN and V. P. BARANNIK. *Uspekhi Khim.*, **19**, No. 5, 641-642 (1950).

It is generally stated in treatises on acid corrosion of metals that the systematic experimentation in this field belongs to the present century. It may be noted, however, that as early as 1881 Kayander published an investigation on many aspects of the dissolution of metals in acids. *Zhur. Russ. Fiz. Khim. Obshchestva*, **13**, Part I (1881). Two other early Russian works are: Onufrovich. *Zhur. Russ. Met. Obshchestva*, 203 (1910), on the rusting of roof iron, and *Kuklin, ibid*, 238 (1910), on the hydrogen brittleness of metals.—NSA.

1.1

**Some Historical Developments Relating to Corrosion.** W. LYNES. Revere Copper & Brass Incorp. *J. Electrochem. Soc.*, **98**, No. 1, 3C-10C (1951) Jan.

A chronological arrangement of some developments relating to corrosion. References are given to papers and patents that were considered to be among the significant contributions to the advancement of the understanding of its nature, or control of its manifestations. Excerpts from a few of the earlier papers including, the electrochemical theory of corrosion, oxygen depolarization, differential oxygen concentration cell, differential solution concentration cell and passivity and corrosion of iron are given.—INCO.

## 1.2 Importance

1.2.5, 6.5

**Metal Poisoning.** P. ROSS. *Brit. J. Industrial Safety*, **1**, No. 12, 204-206 (1950) Spring.

A description by an industrial medical officer, of the mechanism of metal poisoning, the behavior of metal particles when absorbed in the body and the symptoms and effects of metal absorption. Various suggestions, some of which are legally compulsory, are made for reducing the dangers of metal poisoning. Zinc metal may cause metal fume fever in new workers and in others returning to work after a longish absence, but it has no permanent effect. Zinc salts, particularly the chloride, may give rise to dermatitis and caustic burns, so that particular care must be exercised when zinc chloride soldering fluxes are used. The fumes of cadmium or its oxide are dangerous and may cause acute poisoning, metal fume fever, gastritis, bronchitis or pneumonia; the maximum safe concentration of cadmium fumes is 0.1 mg. per cu. ft.—ZDA.

## 1.5 Directories

1.5, 4.3.1, 6.1

**Materials of Construction.** S. D. KIRKPATRICK (Ed. Dir.) and J. R. CALLAHAM (Ed). *Chem. Eng.*, **57**, No. 11, 107-154 (1950) Nov.

Construction materials are given for acetic acid, ammonia, caustic soda, chlorine, fatty acids, hydrochloric acid, hydrofluoric acid, nitric acid, phosphoric acid, sodium chloride, sulfur, sulfur dioxide and sulfuric acid. In directory of materials, trade names, manufacturer, composition and the most important application are given for metals and alloys carbon and graphite, cement and mortar, ceramics, plastics, refractories, and rubber. A list of the authors who discuss important constructional materials is given.—INCO.

## 1.6 Books

1.6, 1.5, 8.8.1

**Materials of Construction for Chemical Process Industries.** J. A. LEE. Book, 1950, 468 pp. McGraw-Hill Book Co., New York and London. $6.50..

This is a compilation of information on materials of construction used in the production and handling of over 300 chemicals, mixtures, foodstuffs, etc. In most cases methods of production (often with flowsheet) are outlined, then materials employed for the more important items of process equipment, for storage and for shipment are discussed. Reference is made to published papers containing more detailed information. This book will be invaluable as a preliminary guide in selecting materials, although actual tests may then be necessary before a final choice is made.—BNF.

1.6, 5.9.4

**Die Phosphatierung: Wissenschaftliche Grundlagen und Technik.** VON WILLI MACHU. Pp. xii + 306, 1950. Weinheim/Bergstrasse: Verlag Chemie G.m.b.H. (Geb., DM 26.-.)

Almost all the available scientific data on the phosphate treatment of metal surfaces has been published in Germany, where there is a well-established school of workers in the field. As an acknowledged member of this, Dr. Machu, who has contributed much to knowledge of the fundamental principles of the process, is well suited to describe their work. This he has done most successfully in the first eight chapters of his book, which deal with the relevant phosphate chemistry, the physical and electrochemistry of the process, types of processing solutions employed and the properties of the phosphate coatings and factors influencing their formation. Material from other sources has, of course, been included wherever possible. The next three chapters, dealing with the phosphate treatment of zinc and magnesium and their alloys, aluminum, copper, nickel, cadmium, and tin, are disappointing in that they are largely a summary of patent claims, and little indication is given of the industrial possibilities, if any, of the patents. The extensive use in the United States of a thin layer of electrodeposited zinc on steel sheet or strip followed by phosphating and painting, and the large spray or immersion plants for phosphating aluminum, barely receive a mention.

There follows an interesting account of the German work on the development of cold phosphate treatments and, with the exception of the last four chapters, the remainder of the book is devoted to phosphating technique. These final chapters deal with phosphating for assisting the lubrication and the cold working of metals, reasons for the production of faulty coatings, and a survey of methods of testing the processing solutions and coatings produced. The description of phosphating technique and plant is largely confined to German procedure, and in consequence the book is not completely up to date with regard to the latest American and British developments.—MA.

1.6, 6.1

**Engineering Materials and Processes: Metals and Plastics.** WILLIAM HOWARD CLAPP and DONALD SHERMAN CLARK. Second edition. 1949. Scranton, Pa.: International Textbook Company. ($6.50.)

With the exception of one chapter, on plastics, rubber, and synthetic elastomers, this volume is concerned entirely with the production and properties of the metals and alloys of general interest in engineering. It may be divided roughly into the first 350 pages, which deal with the metallurgical aspects of the subject, and the later 150 pages, which are specifically concerned with machine-shop practice.

The authors give a general discussion of the mechanical properties of engineering materials and then pass on to consider the structures of metals and alloys. Chapter 3 is concerned with cooling curves and equilibrium diagrams, necessarily, in the twenty pages available, in the merest outline. The manufacture of iron and steel is then considered, and their heat-treatment is discussed in Chapter 5. The alloy steels and cast irons are next briefly reviewed. As is not infrequently the case, the nonferrous metals and alloys take a definitely second place, and the discussion of their properties and uses in Chapter 7 extends over only twenty-one pages. There is then a general description of the production of castings, and of hot- and of cold-working. The chapter on the of space, is good.
joining of metals, within the limitation

So far as the reviewer has been able to determine, the factual matter is accurate. The illustrations are pertinent and good, and the book as a whole presents in outline a reasonable picture of the metallic materials which the normal engineer has at his disposal.—MA.

1.6, 3.5.9, 3.7.3, 3.2.3

**Properties of Metals at** Elevated Tem-

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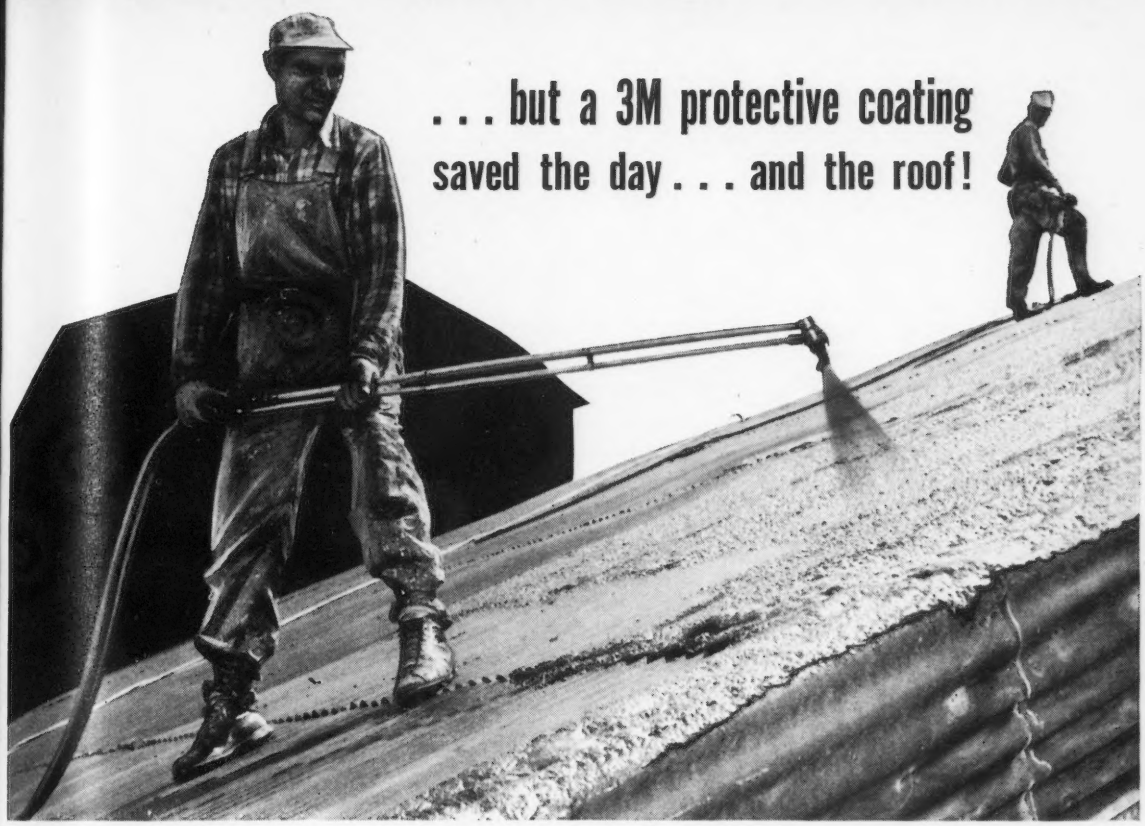


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**peratures.** GEORGE V. SMITH. 401 pages. 1950. McGraw-Hill, New York. (TA460 Sm51p.)

Summarizes available knowledge on the above. Considers fundamentals of plastic deformation and fracture at ordinary and elevated temperatures. Describes test apparatus and test procedures for evaluating metals for high-temperature service. Summarizes available information on effects of chemical composition, manufacturing practice, heat treatment, etc. Scaling and changes in microstructure during service are discussed. Considers the problem of design, particularly choice of working stress. Includes tables, graphs, and illustrations.

## 1.7 Organized Studies

1.7.1, 5.2.1

**Joint Cathodic Protection Systems.** *Petroleum Engr.*, **23,** No. 2, D53-D55 (1951) Feb.

This is Bulletin 4 of the series on cathodic protection prepared by the Correlating Committee on Cathodic Protection sponsored by 11 organizations. It discusses the techniques of joint systems design and installation, possible division of responsibility for their construction, operation and maintenance, and the sharing of costs. The principal points to be included in any agreement between the structure owners are also outlined.

1.7.2, 2.2.2

**ASTM Atmospheric Exposure Tests for Corrosion.** *Oil Gas J.*, **49,** No. 36, 51 (1951) Jan. 11.

Tests are being concentrated at seven sites carefully selected for specific types of corrosion, from tropical conditions in the Canal Zone to a frigid climate in Canada. Other stations will be set up in New York City, Columbus, O., Pennsylvania State College, Kure Beach, N.C., Port Aransas, Tex., and Port Reyes, Cal. The new test sites will be equipped to study the effects of atmospheric deterioration on plastics, rubber, textiles, wood and other engineering materials as well as on metals. The long-range program also includes the establishment of several underwater sites. ASTM estimates annual loss due to metal corrosion at over a billion dollars.

# 2. TESTING

## 2.1 General

2.1.2

**Simulated Corrosion Tests.** *Machine Design,* **1951,** 86, Jan.; *Gaylor Tech. Sur.* 7. 84 (1951) Feb. 3.

Simulated corrosion tests are claimed to have no correlation with actual corrosion; tests over 15 years have indicated that actual environmental conditions only will give useful results. According to F. L. LaQue of Inco Harbor Island Corrosion Testing Station, "there is no indication of relative merit among various metals concerning their corrosion resistance."

## 2.2 On Location Tests

2.2.6, 4.5.4

**Pipe-To-Soil Potentials as an Indication of Corrosion. I and II.** M. E. PARKER. *Oil Gas J.*, **49,** No. 43, 65-66 (1951) Mar. 1; No. 44, 95-107 (1951) Mar. 8.

2.2.6, 8.9.3

**Corrosion and Its Control: How to Locate "Hot Spots."** M. E. PARKER. *Oil Gas J.*, **49,** No. 41, 116-117 (1951) Feb. 15.

The single-rod method of surveying a bare pipe-line, and the interpretation of the soil resistivity profiles thus obtained to determine the location of "hot spots," or joints of especially rapid corrosion, are discussed.

2.2.2, 5.4.5

**Outdoor Exposure Results of Clear and Pigmented Pure Liquids at the Six Months Period.** *Official Digest Federation Paint & Varnish Production Clubs,* No. 311, 1033-1041 (1950) Dec.

A report on the outdoor tests made with 23 pure paint vehicles, both clear and pigmented with a mixture containing 75 percent titanium dioxide and 25 percent acicular lead-free zinc oxide. The paints and varnishes were applied to glass panels under carefully controlled conditions. Some of the specimens showed early failure, and all had lost their gloss within 16 weeks except a commercial alkyd enamel used as a control. The various failures are discussed and some are illustrated.—ZDA.

2.2.2, 5.4.5

**Paint Testing in South Florida.** O. J. SIEPLEIN. *Official Digest, Federation Paint & Varnish Production Clubs,* No. 303, 309-314 (1950).

Testing grounds in S. Florida for outdoor exposure tests on paints are described. Weather records indicate that panels at 45° in S. Florida receive throughout the year an intensity of sun energy comparable with that for the summer months in Northern U. S. A. Tests on various types of finish indicate that 1 year of exposure in Miami is as severe as 3 years in Chicago.—RPI.

2.2.2, 4.2.8, 5.4.5, 1.7.1

**Outdoor Exposure Results of Clean and Pigmented Pure Liquids at the Six Months Period.** *Am. Paint J.* (Convention Daily), **35,** 10-16 (1950) Nov. 17.

Give details of experimental work on the above by the C-D-I-C Club. The 23 liquids were pigmented with 30 percent by volume of pigment in the dry film. The pigments consisted of 75 percent specular titanium dioxide and 25 percent acicular, low-oil-absorption, lead-free zinc oxide. A calculated amount of drier was added to each paint 72 hours before application. The paints were accurately applied to glass panels. After drying under uniform conditions of temperature and humidity for 10 days, the panels were exposed in a semi urban area. Weekly examinations were made. Typical results are illustrated and discussed.—BLR.

2.2.2, 5.4.5

**Weathering Tests on Zinc Oxide Paints.** J. R. RISCHBIETH. *J. Oil Colour Chemists' Assoc.*, **33,** 471-476 (1950) Nov.

Describes results of Australian research on various types of the above. Effects of pigment variation, of primer, of acid value of vehicle, of bodied oil, of period of standing after milling, of water spraying of panels and of summer and winter exposure were determined. —BLR.

2.2.2, 5.4.5, 4.2.1

**Exterior Paints for Woodwork.** B. ANDERSSON AND P. NYLEN. Statens Kommittee for Byggnadsforskning, Bull., 1950, No. 16, 91 pp.

Programs of three extensive series of natural exposure tests commenced in Sweden in 1944, 1947 and 1948 are described. The painting system in the 1944 series consisted of oily primers, undercoat and finishing coat, applied to pinewood panels and exposed at Stockholm. After 5 yr. exposure the following conclusions were drawn; pretreatment of the wood with preservatives prior to painting may impair durability; the nature of the pigment, e.g., white lead, zinc oxide, ochre or lithopone, in the priming coat has little influence; lithopone as the sole pigment in the undercoat results in early failure with typical alligatoring; addition of linseed stand oil or, even better, linseed/tung stand oil to boiled linseed oil in the top coat causes marked improvement; white lead in the top coat shows no clear superiority over zinc oxide and chalks almost as badly as anatase titanium dioxide. The 1947 series was mainly confined to studying the influence of the composition of the primer on durability, both pigmented and clear oil primers being tested. The only general result apparent after 22 months is that priming oils containing polymerized oil in the binder gave inferior durability, causing cracking and in some cases flaking. Addition of considerable quantities of solvents or pigments to the polymerized oil improves durability. In the 1946 series English, American and Swedish painting systems are being compared.—RPI.

2.2.3, 4.2.3, 4.3.5

**The Corrosion of Mild Steel by the Products of Combustion of Gaseous Fuels.** H. A. PRAY and others. Amer. Gas. Assoc. Committee on Domestic Gas Research, Report No. 2, Aug., 1949, 50 pp. Obtainable from Battelle Memorial Institute. 75 cents.

Describes corrosion-testing equipment developed for examining materials in flue gas under various conditions of operation and temperature, with detailed results of tests of SAE 1010 steel at sulfur levels of 0-50 grains per 100 cu. feet of 1000 B.T.U. fuel gas (natural gas), and under a variety of conditions up to 400°F (204°C).

2.2.3

**Practical and Relative Simple Corrosion Tests Found Effective.** F. L. LAQUE. International Nickel Co. *Petroleum Refiner,* **30,** No. 2, 120-122 (1951) Feb.

Simple tests are described that can be applied in the plant for determining corrosion effects and selecting suitable construction materials.

2.2.5, 1.3

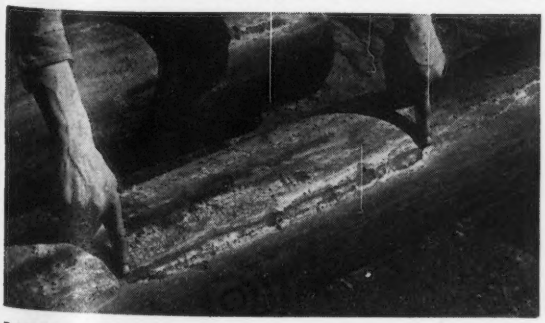
**Corrosion Tests on Metals Coated with Paint.** A. FERRI. *Pitture e vernici,* 6, No. 8, 329-332 (1950).

A review.—RPI.

2.2.5, 5.4.5

**Dow Draws Conclusions from Three-Year Paint Study.** O. K. SIEPLEIN. Sherwin-Williams Co. *Chem. Eng.*, **57,** No. 10, 110-115 (1950) Oct.

Report of the results of various paint coated specimens exposed to corrosive atmospheres. Exposure areas contained vapors and fumes of hydrochloric acid, mercuric chloride, chlorine and carbon tetrachloride and salt water mist from the Gulf of Mexico. The protection of



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various finish coats and primers are summarized. The outstanding protection is afforded by Primer A-Finish M (medium oil butyl-phenolic vehicle). Finish N (medium oil para-phenyl-phenolic counterpart of Finish M) showed early fading. Oleoresinous coatings showed quicker loss of gloss and alkyd and chlorinated rubber finishes lost protection more rapidly after the first year than did phenolics and oleoresins.—INCO.

2.2.5

**Exposure Testing.** N. R. Fisk. *Paint Technol.*, **15**, No. 175, 287-290 (1950).

Natural exposure testing is discussed. The variability of weather factors makes haphazard exposure work of little value. Small-scale exposures of the same paint systems at different seasons and on different sites are advocted.—RPI.

## 2.3 Laboratory Methods

2.3.1, 5.4.2

**Some Test Results From an Industry-Wide Research Program.** F. A. Petersen. *Better Enameling*, **21**, 16-19 (1950) Dec.

Outlines results of work on standard test methods done by the Dept. of Ceramic Engineering, University of Illinois, for Enamel Utensil Manufacturers' Council since 1940. Tests developed or improved were for enamel thickness, resistance to food acids, and wear resistance. Data are charted.—BLR.

2.3.1, 4.4.7

**The Testing of Lubricants.** (In English.) C. S. Windebank. *Schweiz. Archiv angew Wiss. u. Tech.*, **16**, 243-253 (1950) Aug. discussion, 253-254.

Discusses advantages and disadvantages of various methods for the above. They are classified as service trials, field tests, rig tests, accelerated tests, and simulated tests. Considers lubricant specifications, tests for fundamental properties, significance of data, and use of the methods in development of new products. (Summary and discussion in German.)

2.3.2, 1.7.1, 2.3.4

**Laboratory Corrosion Testing of Chemical-Resistant Paints.** R. R. Rogers and W. Dingley. *Finish*, **7**, 23-26, 75 (1950) Nov.

Presents progress report on Canadian government research program being carried out to obtain performance information on chemical-resistant paints. Seven commercial paints were applied to steel panels and subjected to various types of exposure. Data are tabulated and charted; results are illustrated.—BLR.

2.3.2

**Resistance of Various Finishes to Salt Spray Corrosion.** N. H. Godbold. Board of Trade Tech. Inf. & Docs. Unit, ORR. 463/50; PB. 86112, Frames 8.

2.3.2

**Salt Spray Test of Metal Panels.** J. L. Basil. U. S. Naval Engineering Experiment Station, Annapolis. Report 4A17X1603.

Salt spray tests were conducted on aluminum disks, on aluminum disks in contact with strips and bolts of Monel metal and stainless steel, on aluminum panels sprayed with aluminum alloys, and on aluminum and metallized aluminum coated with paint.

Aluminum specimens corroded severely and the corrosion was accelerated when the metal was in contact with stainless steel and Monel metal.

Some areas of the alloys sprayed on the aluminum were cracked and apparently raised from the basic metal surface. Under salt-spray conditions corrosion is accelerated by galvanic action; raising of the sprayed deposit by corrosion products can be expected.

On painted specimens, the paint system generally broke down at the edge of the metallized areas and at rivets and lock bolts. It is possible that the paint may have absorbed sufficient moisture to dampen the underlying metal at the edge of metallized areas and that blistering was caused by electrolytic action. Around rivets and lock bolts minute crevices not sealed by paint may allow salt solution to penetrate to the bare metal.

The specimens were exposed under ultraviolet light to 3-minute cycles each of a hot-air blast and a spray of 20 percent sodium chloride solution, both at 135°F. The specimens were inspected at 7, 48 and 100 hours. The compositions of the aluminum specimens and alloy coatings are not given.—PDA.

2.3.2

**The Corrosion of Metals and Metal Finishes Under Humidity And Salt Spray Tests; An Analysis of Four Years Tests at T.R.E.** G. W. A. Drummer. Gt. Brit. Telecommunicatons Research Establishment, Gt. Malvern. Technical Note 50, Oct. 1949.

Finished and unfinished metals and alloys were exposed to humidity and salt spray tests for 4 years. Outstanding corrosion resistance was exhibited at Birmabright BB1 aluminum alloy and by 18-8 type stainless Steel. Birmabright, especially when self-finished, is a promising material for chassis of airborne radar equipment; stainless steel, because of its great mechanical strength, offers greater advantage for framework in panclimatic radar equipment. Stainless steel nuts and bolts have effectively combated the difficulties normally involved in removing badly corroded nuts and bolts made of ordinary steel.

Of various conductive coatings on aluminum alloys, platings of silver, copper, cadmium and nickel did not withstand salt spray exposure. Platings processed by some of the more recent methods withstood reasonable periods of humidity cycling. Of the nonconductive coatings on aluminum, an anodized finish was the most satisfactory. Some of the earlier stove-enameled finishes were inadequate, but those produced by later processes offered considerably better protection.

Lacquer finishes on brass did not adequately protect against both humidity and salt spray. In limited tests, nickel-plated brass was reasonably effective.

No serviceable protective finish seems to exist for magnesium alloys exposed to both humidity and salt spray. A complete coating of polyethylene, although effective, was too thick for practical purposes. All platings tested were approximately 0.001 in. thick; 0.005 in. coatings would afford greater protection.

Against humidity exposure, tin-zinc plating was the most effective finish on steel. A chassis plated with zinc and overplated with a tin-flash withstood over 400 humidity cycles. Most of the finishes tested did not resist both humidity and salt spray. Passivation over a normal finish prolonged resistance but did not give complete protection under these conditions. Galvanizing appeared very satisfactory under prolonged humidity exposure. Recent nonconducting paint finishes, both air-dried and stoved, were very promising.

On magnetic materials, beryllium-copper and Mumetal proved to be the least affected by humidity cycling, but most ferrous metals showed varying degrees of corrosion.—PDA.

2.3.2

**Accelerated Weathering: So Called.** P. J. Gay and Others. *Paint Technol.*, **15**, No. 174, 247-248 (1950).

Discussions on a lecture previously reported. Topics raised included substrates used in accelerated weathering, temperature control, oxygen treatment and effect of vibration and soot contamination.—RPI.

2.3.2, 6.6.5

**A Sulfate Susceptibility Test for Portland Cements.** W. C. Taylor and R. H. Bogue. *J. Research Nat. Bur. Standards*, **45**, 223-231 (1950) Sept.

Describes procedure by means of which Portland cements may be given ratings indicative of their resistivity to chemical attack by sulfate-containing solutions. The test may be performed in about a day as contrasted with usual performance tests which require weeks or months.

2.3.2, 3.7.3

**Results of Recent Tests on Resistance to Weld Decay of Low-Carbon Stainless Steel** G. R. Bolsover. *Sheet Metal Inda.*, **28**, 73-76 (1951) Jan.

Presents results of tests on a series of British compositions in which the specimens were reheated to 650° C for 30 minutes, immersed in a boiling cupric sulfate-sulfuric acid solution for 72 hours, bent 90° over a radius of 3t and examined by the naked eye for signs of intergranular collapse on the surface. Data are tabulated.—BLR.

2.3.2, 5.5.3

**A Method for the Evaluation of Soft-Film Temporary Corrosion Preventives for Ferrous Articles.** T. P. Hoar and G. C. Smith. *J. Inst. Petroleum*, **36**, 448-457 (1950).

The authors believe that the most rational evaluation of soft-film temporary corrosion preventives should be a test of a mechanically poor coating under relatively moderate conditions. A very thin but reproducible film is deposited from a volatile solvent on a clean steel surface, and the incidence of corrosion caused by small drops of distilled water is determined after 24 hours. The composition of three parts mineral jelly with one of lanolin is shown to be considerably better than plain jelly. It is further improved by the substitution of wool-grease for lanolin. The addition of 2 percent of sodium petroleum sulfonate to mineral jelly greatly improves its protective value.—PR.

2.3.2, 5.4.5

**Influence of Pigments on the Effec-**

tiveness of Coatings as Corrosion Preventives. (In German.) C. KALAUCH. *Werkstoffe u. Korrosion*, **1**, 400-404 (1950) Oct.

Describes comparative experiments made to determine the protective effects of inorganic and organic basic pigments in coatings against oxygen-water corrosion of iron. Tödt's current-time measuring method was used. The mechanism of corrosion of coated metal surfaces is briefly explained. Diagrams and graphs are included.—BLR.

2.3.2

**"AC" (Alternate Condensate)—A New Corrosion Test.** THOMAS E. LLOYD. *J. Metals*, **188**, No. 9, 1092-1093 (1950).

The alternate condensate method for corrosion testing methods on coatings uses water in the form of condensate or dew to produce the corrosive action; it is particularly effective as water in this form is of max. corrosivity in most intimate contact with the surface of the sample, and actually searches out pinholes and never bridges them. The test closely simulates actual weathering conditions in areas not affected by salt spray or salt air, and produces in a 4-min. time cycle the weathering action of a full 24 hr. of an area where dew is of nightly occurrence. It can be adapted to a variety of conditions, as specimens can be exposed to varying temp. and humidities, as well as to air carrying desired contaminants in controlled quantities. The apparatus con-

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sists of a turntable upon which samples are mounted, and chambers or tunnels through which the specimens mounted on the turntable pass, so that they are exposed to the atmospheric conditions of each chamber. The cool, dry sample passing into the first chamber comes into contact with a stream of warm, humid air, which causes it to become rapidly covered with a film of condensed moisture, which remains on it as it passes through the chamber. The sample then passes to the second chamber, where it encounters a stream of cool, dry air, which rapidly removes the moisture from it. If sulfur dioxide, hydrogen sulfide, or other contaminants are desired, they can be introduced in a chamber arranged to follow the condensing chamber. After drying and cooling, the sample again enters the first chamber, where the cycle begins again. These alternate exposures to cool dry and warm humid conditions cause rather rapid corrosion of the test specimens, and are more clearly an accelerated reproduction of the actual corrosion conditions most commonly met than most other accelerated tests.—MA.

**2.3.3, 3.3.4, 6.6.10**

**Microbiological Deterioration of Organic Materials: Its Prevention and Methods of Test.** E. ABRAMS. PB. 99549; *Bibl. Tech. Repts.*, **13**, 114 (1950); *Nat. Bur. Stand.*, **1948**, 44 pp. Nov.

A detailed review is given of the literature on the microbiological deterioration of organic and fibrous materials. Representative problems incidental to the development of test methods for the evaluation of mildew-resistance and the development of mildew-resistant materials are given. The most widely recognized test methods for the evaluation of mildew-resistance and rot-resistance are listed. A wide variety of fungicides for different uses is classified according to effectiveness. Plastics, plasticisers, etc. are rated according to their susceptibility to support mould growth.—RPI.

**2.3.3, 5.4.7**

**Tests on Various Antifouling Preparations.** Board of Trade, Tech. Inf. & Docs. Uni. Frames, 1-115; FD. 1126/50.

Antifouling coatings containing copper and/or mercury were tested, and the presence of copper in the binder shown to be beneficial. The rates of solution of poisons from the coatings were measured.—RPI.

**2.3.3, 2.3.4**

**Solubility and Estimation of Poisons Used in Anti-Fouling Paints for Ships.** M. RAGG. *Farbe u. Lack*, **56**, No. 10, 435-441 (1950).

Only those poisons whose lethal concentrations and sea-water solubilities lie within certain limits are useful. The solubilities of mercuric oxide, zinc oxide, arsenous oxide and several copper compounds were measured. Chemical reactions between the substances and sea water are suggested. The concentration of copper ions in sea water is determined by the solubility of copper carbonate, the least soluble of the salts possibly formed in sea water. A description is given of a sensitive dithizone method for estimating mercury, zinc and copper in concentrations of the order of 1 g. per liter.—RPI.

**2.3.4, 6.3.7, 6.3.8**

**New Indium-Bearing Solders Have Improved Alkali Resistance.** S. M. GRYMKO AND R. I. JAFFEE. *Materials and Methods*, **31**, No. 3, 59-60 (1950).

Corrosion tests in 25 percent potassium hydroxide at 50°C were carried out on joints soldered with various lead-tin solders containing indium. Alloys containing more than 25 percent indium were found to be very corrosion-resistant. The strongest solder was found to be one containing indium 25, lead 37.5, and tin 37.5 percent; this alloy showed an appreciable increase in shear strength after exposure to 25 percent potassium hydroxide at 50°C for 1 month, which may have been due to an age-hardening effect. The liquidus and solidus temp. of this alloy were found to be 180° and 135°C, respectively. Alloys without or with 10 percent indium were penetrated by the alkaline solution. Wetting tests indicated that the wetting properties of the 25 percent indum alloy were rather better than those of the 50 : 50 lead-tin solder.—MA.

**2.3.5**

**A New Corrosion Testing Technique.** *Oil, Paint Drug Reptr.*, 159, No. 9, 40 (1951) Feb. 26.

A new corrosion testing technique has been developed by the Armour Res. Foundation under the sponsorship of the NACA. A metal cylinder is dipped in the corrosive solution, rotated several hundred times a minute and scanned with a stationary probe electrode. The electrode picks up the minute electrical current caused by the corrosion thus enabling measurement and study of the corrosion process.

**2.3.5, 4.3.6, 3.4.7**

**Cathodic Efficiency of Metals, Especially of Aluminum in Common Salt Solutions.** (In German.) RICHARD ERGANG AND GEORG MASING. *Z. Metallkunde*, 41, 272-279 (1950) Aug.

Presents and discusses results of experiments on iron, cadmium, copper, platinum and aluminum in their various binary combinations, in 3 percent sodium chloride solutions of different pH's and for various periods of time. Data are tabulated and charted.—BLR.

**2.3.5, 3.4.3, 5.8.3**

**Rust Formation and the Action of Red Lead; A New Investigation.** MANFRED RAGG. *Paint, Oil, Chem. Rev.*, **113**, 21-22+ (1950) Oct. 26.

Describes experimental work in which voltages occurring in a model iron-carbon cell were determined as an indication of the magnitude of those which occur in "local cells" during corrosion of iron and steel, and to help clarify the mechanism of action of red lead. The model cell consisted of an iron rod 7.8 mm. in diameter and a carbon electrode immersed in a 0.5 percent solution of sodium chloride. In later experiments, a dispersion of red lead was added. Results are tabulated and analyzed.—BLR.

**2.3.5, 5.8.2**

**Electrochemical Analysis of the Anti-corrosive Action of Emulsifiable Oils.** A. FERRI. Paper, 23rd Congress de Chimie Industrielle, Milan, Sept. 1950. *Abstr. Chim. Ind.*, **64**, No. 3, 80 (1950) Sept.

The corrosion-inhibiting action of aqueous emulsions used as cutting oils is shown to be due to the local pile effect of the oil at the anode. Since the oils appear to be of the anodic inhibitor type, local corrosion may occur in special cases. An electrochemical study was made of a series of water-oil systems with the addition of auxiliary inhibitors of the cathodic type. The best results were obtained with potassium bichromate.

**2.3.5, 3.6.9**

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trolysis. I. The Nature of Polarization Capacity and Polarization Resistance. MANUEL SHAW AND A. EDWARD REMICK. II. Oscillographic Studies. JACOB SILVERMAN AND A. EDWARD REMICK. *J. Electrochem. Soc.*, 97, 324-345 (1950) Oct.

The work reported in Part I involves impedance-bridge measurements on electrolytic cells subjected to alternating currents. A study of the cleaning and conditioning of platinum electrodes was followed by a study of reversible and irreversible oxidation-reduction systems. Relationships among polarization capacity, polarization resistance, reversibility, frequency, current density, concentration, and redox ratio were studied. In Part II, Reichenstein's oscillographic study of the a.c. electrolysis of aqueous sulfuric acid was repeated. His contention that instantaneous value of cell voltage at zero instantaneous current, corrected for iR drop, approaches a limiting maximum value as rms. value of the current increases was found to be true; but his statement that this maximum voltage is the thermodynamic decomposition potential of water was not verified. This voltage was found to include the associated overvoltage. Oscillographic studies were also made on two reversible redox systems. Variations produced by changes in current density, concentration, frequency and redox ratio were explained qualitatively. —BLR.

2.3.5, 1.7.1, 2.3.4, 5.4.5

**Water and Alkali Tests—Project No. 9.** *Am. Paint J.* (Convention Daily), **35**, 20-23 (1950) Nov. 16.

Describes ASTM Test for Varnishes (D154-47) and points out its drawbacks. Gives details of development of improved procedures for casting of uniform films of controlled and predictable thickness. In most cases, results were satisfactory, but some of the special oils exhibited very poor wetting properties on contact with glass panels. Water and alkali immersion tests were performed on films prepared from 24 oils. Results are tabulated and discussed.—BLR.

2.3.5

**Measurement of Potentials in Corrosion Research.** (In German.) C. MASING. *Werkstoffe u. Korrosion*, **1**, 433-437 (1950) Nov.

Presents examples and graphed data to show how a simple but systematic study of the potentials of a given metal electrode in an electrolyte can materially aid in understanding of the reactions occurring at the electrode; and, hence, the corrosive behavior of the metal. Aluminum and aluminum-copper-magnesium in buffered sodium chloride solution, iron in buffered acetic acid, zinc in sodium sulfate solution are cited.

2.3.7, 5.4.5

**Testing Techniques and Uses of Equipment for Evaluating Organic Coatings.** R. J. PHAIR. *Paint Varnish Production Mgr.*, 30, 8-11 (1950) June; 12-15 (1950) July.

Part I is concerned with the measurement of coating thickness, distensibility, and adhesion of finishes for metal products. Part II covers mar testing, impact resistance, abrasion and hardness testing, and some special tests for wood lacquers.—BLR.

2.3.7, 6.2.2, 6.2.3

**Variation of the Bending Strength of Cast Iron During Long-Time Corrosion Testing.** (In German.) FRANZ ROLL. *Neue Giesserei*, **37** (new ser., v. **3**), 337-339 (1950) Aug. 24.

Reports results of transverse-bending tests made on three different cast irons and one steel exposed to sea water and to the atmosphere for up to 10,000 hr. Apparatus is diagrammed; data are graphed and tabulated.—BLR.

2.3.7, 3.5.3

**Production by Cavitation of Foams in Lubricating Oils.** (In German.) G. VOGELPOHL. *Forschung auf dem Gebiete des Ingenieurwesens*, sec. B, **16**, No. 4, 109-112 (1949-50).

Conditions of cavitation in oil were studied with the help of a nozzle of rectangular cross section with parallel glass walls on opposite sides. In this way formation of bubbles in the oil passing the nozzle was observed and photographed. Experiments under different conditions show that cavitation increases with temperature and with pressure drop in the nozzle. Quantity of foam depends on intensity of cavitation. Diagrams and illustrations.—BLR.

2.3.7, 5.4.5

**High- and Low-Temperature Resistance of Bituminous Paints Used for the Protection of Buildings and for Corrosion Prevention.** (In German.) HANS NUSSEL. *Arch. tech. Messen*, 1950, T127-T128 Nov.

Describes various methods of testing the above. Low-temperature resistance is measured with the aid of bending, impact, and shatter tests. Includes diagrams and a photograph.—BLR.

Fight Corrosion with Chromate Pigments

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2.3.7, 5.4.5

**Methods of Testing Adhesion of Paints.** R. QUARENDON. *Paint Manuf.*, **20,** No. 12, 427-433 (1950) Dec.

A review of the various tests which have been devised for measuring the adhesion of a paint film to the basis metal. The tests are classified as direct adhesion, deformation, scratch or impact tests and some 20 methods are described. The author points out that only a few of these tests give results relatively unaffected by properties other than the adhesion of the paint film. For this reason the various methods should be regarded as complements rather than as alternatives and he concludes by saying that at present there is no laboratory test which is capable of replacing the practical experience of the skilled examiner.—ZDA.

2.3.7, 5.4.8

**Discussion of Paper on Electrical Method for Evaluation of Protective Coatings as Moisture Barriers.** W. C. ELLIS, reviewed *ASTM Bull.*, No. 166, 51-53 (1950) May.

The coatings used for protective coatings as moisture barriers and methods of testing are discussed. Phenolic paint and lacquer (No. 4) is considered to be of interest as a protective coating for insulation-resistance properties of moisture-absorptive materials during use or storage in tropical areas. Coating No. 4 is a single dipcoat of Rustban No. 270 followed by a single dipcoat of Roxyn 11C. The method of applying the varnish and the procedure in immersing the specimen in water and subsequent drying and testing are discussed with regard to a bakelite specimen.—TDD.

2.3.7

**Photoelastic Study of the Tensions on the Matthaes' Sample For Strained Corrosion Tests.** (In Italian.) W. RUFF. *Alluminio,* **19,** No. 5, 411-415 (1950).

The distribution of the tensions on the Matthaes' sample suitable for strained corrosion tests was determined by photo-elastic methods. The factors of the tension concentration are established which show good agreement with those already determined in a previous study by the tensile test performed on a compressed model in Superavional D alloy.—ALL.

2.3.8, 7.1

**Weigh Engine Wear Factors in Man-Made Dust Storm.** *SAE Journal,* **58,** 46-51 (1950) Oct.

Excerpts from "Engine Wear as Affected by Air and Oil Filters," by W. S. James and B. Gratz Brown. Gives details of automotive-engine tests run in a "Dust Tunnel," showing effects of different types of air cleaners, of oil filters and of chromium-plated top rings. Effects of increased plating thickness was also determined.—BLR.

2.3.9, 5.8.3

**Orientation of Fatty Acid and Soap Films on Metal Surfaces.** J. W. MENTER AND D. TABOR. *Proc. Royal Soc.*, ser. A, **204,** 514-524 (1951), Jan. 9.

An electron-diffraction study was made of the structure and orientation of the above. An examination was made of effect of temperature on orientation, using the reflection method and an improved experimental technique. The results show that, at room temperature, the first layer is generally orientated with the hydrocarbon chains normal to the surface, though other orientations may be obtained by "rubbing" the film. As the temperature is raised, the "layer lines" become less distinct, and at a characteristic temperature only the pattern of the substrate is observed. At higher temperature, the film may evaporate completely from the surface. On non-reactive metals such as platinum, the disorientation temperature is close to the bulk melting-point of the fatty acid. On reactive metals such as zinc and cadmium, disorientation occurs at a higher temperature close to the bulk melting point of the corresponding metallic soap. These observations are compared with the lubricating properties of fatty acids and soaps on metal surfaces.—BLR.

2.3.9

**The Electrolytic Polishing of Zirconium and Its Application to a Study of the Effects of Abrasion Upon the Structure of the Metal.** P. A. JACQUET. *Metallurgia,* **42,** No. 252, 268-270 (1950) Oct.

The difficulties attendant on the preparation, by normal metallographic procedures, of etched specimens of zirconium suitable for microscopic examination, emphasize the importance of electrolytic methods of polishing. In this article, Dr. Jacquet deals briefly with the methods which have proved satisfactory and with their application to a study of the effect of abrasion on the structure of the metal.—TDD.

2.3.9, 5.8.3

**The Adsorption of Hydrophobic Monolayers of Carboxylic Acids.** H. R. BAKER, E. G. SHAFRIN AND W. A. ZISMAN. Paper A.C.S. Colloid, Chem. Div. Symp. on Surface Chemistry in Corrosion, 119th Meeting, Cleveland, Apr. 9-12, 1951.

A previously reported contact angle method has been extended to the study of the adsorption from aqueous solution of a variety of types of mono and dicarboxylic acids.

2.3.9, 5.9.1, 5.8.3

**The Application of Radioactive Tracers to the Study of Metal-Solution Reactions.** M. T. SIMNAD. *J. Metals,* **188,** No. 10, 1220 (1950) Oct.

The influence of surface treatment and structure upon the reactions taking place when metals are placed in ionic solutions containing radioactive ions was studied. Radioactive ions of cobalt, chromium, nickel, and iron were used in solutions into which are immersed numerous metals and alloys with various surface treatments. The effects of the presence and absence of oxygen in the solutions and of oxide films on the metals, the influence of time, temperature and pH was then determined. The experiments with radioactive cobalt and chromium indicate that the phenomena of exchange is actually a local electrolysis resulting from differences in electrode potential on the metal surfaces. The experiments with radioactive chromium, in which active chromate ions were used in the solutions, have served to show that passivity in chromate solutions results from the deposition of chromate ions at anodic points on the metal surface, and the distribution of these points following various passivating treatments is brought out in autoradiographs of the specimens.—TDD.

2.3.9

**A Cathode-Ray Polarograph.** F. C. SNOWDEN AND H. T. PAGE. *Anal. Chem.,* **22,** 969-981 (1950) Aug.

Described improved apparatus, using readily available components, and experimental results obtainable with it. It can be used as a qualitative and quantitative analytical tool, for both inorganic and organic systems. In addition, it is capable of following rapid, as well as slow, reactions of zero, first, and second order. —BLR.

2.3.9

**Calorimeter for Some Corrosive Liquids.** B. H. SAGE AND E. W. HOUGH. *Anal. Chem.,* **22,** 1304-1309 (1950) Oct.

Calorimeter described is suitable for measuring heat capacity of corrosive liquids at temperatures up to 400°F. It was constructed of stainless steel containing a large amount of chromium and nickel and was gold-plated on the internal surfaces to decrease further the rate of corrosion by materials such as red fuming nitric acid.—BLR.

2.3.9

**Electron Microscopy; Technique and Applications.** RALPH W. G. WYCKOFF. 248 pages. 1949. Interscience Publishers, New York.

Describes electron microscopes and their adjustment preparations for electron microscopy, metal shadowing and visualization of very small objects, use of surface replicas, particle suspensions, viruses, photography of macromolecules and structure of macro-molecular solids. Includes illustrations and extensive chapter bibliographies.

2.3.9

**Radioactive Tracers in Metallurgy.** W. S. EASTWOOD, A. E. WILLIAMS, H. M. FINNISTON AND W. G. [illegible] *Coal. Trades Rev.,* **141,** No. 4298, 203 (1950).—MI.

2.3.9, 3.2.3

**The Application of Electron Diffraction to the Study of Surface Films on Metals.** H. RAETHER. *Recherche Aeronaut.,* **15,** 45-49 (1950).

Surface films with a thickness of less than 10 Å on metals can be studied by electron-diffraction methods. It is shown from theoretical considerations that the sensitivity of the method is dependent upon the smoothness of the underlying metal surface, i.e. whether optically flat, slightly undulating (electrolytically polished) or rough (sputtered or emeried). Some results from the application of the method to the study of oxide films on zinc and aluminum are presented.—MA.

2.3.9, 8.4.3

**Electron Microscope Research in the Oil Industry.** (In English.) T. REIS. *Proc. Conf. Electron Microscopy,* Delft, July 1949, **1950,** 179-182.

The electron microscope has proved a valuable tool in the laboratories of the French oil industry. Examples are given of studies of particle size and shape determinations, and of clays, catalysts, greases, lubricating oils and carbon black. Among metallurgical applications are studies of corrosion, including research on surface-protecting agents. The micro-structure of surface

damages caused by friction is also dealt with.—MA.

2.3.9, 3.2.3, 6.3.6

**Studies of Copper Surfaces by Low Temperature Adsorption Isotherms.** T. N. RHODIN, JR. *J. Am. Chem. Soc.*, **72**, 4343-4348 (1950) Oct.

True surface areas of metal surfaces as small as 10 sq. cm. were measured with an error of 6 percent from low-temperature adsorption isotherms using a specially designed vacuum micro-balance technique. This method is of special value in determining the average thickness of corrosion films formed by reaction of gases or liquids with solids. Progressive oxidation of a rough polycrystalline copper surface decreased the surface area to a point where the roughness factor approached unity.—BLR.

2.3.9

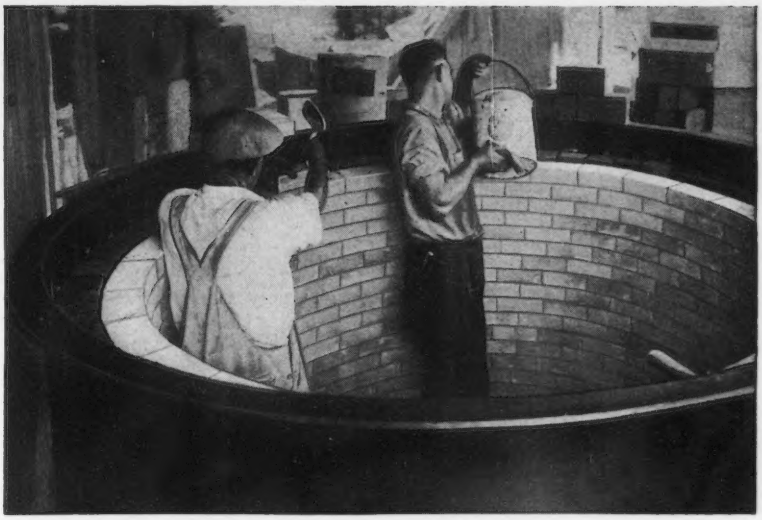
**Character of the Oxidation of a Metallic Alloy by Grinding at Different Speeds in a Rarefied Atmosphere, Examined by the Electron-Diffraction Method: Case of 80 : 20 Nickel-Chromium.** ROBERT COURTEL. *Rev. Met.*, **47**, No. 9, 700,702+ (1950).

Continuing previous work (*ibid.*, 1949, **46**, 24) Courtel applied the technique of electron diffraction to fresh surfaces after very short periods. An investigation, based on the appearance of an identifiable, irreversible phase transformation, into the temperature reached by 80 : 20 nickel-chromium alloy during grinding showed that 400°C corresponded with a speed of grinding of ~15 m. per sec. and 550°-600°C with 25 m. per sec.; but relating the speed of grinding to the temperature introduced difficulties when the crystal phase change came to be explained. In spite of the more marked selectivity of oxidation by purely thermal treatment, there is an analogy between this process and oxidation by grinding; there are nevertheless important differences. In the case of grinding the duration of the reaction is relatively short—of the order of a fraction of a sec. as compared with an hour for thermal oxidation; for fresh surfaces formed by grinding the period of induction is reduced to zero. In the discussion the relatively low temperature attained is attributed to the hardness and brittleness of the abrasive—silicon carbide—used; and it is pointed out that the method is limited to the few cases of irreversible transformation, such as cobalt and the ferro-nickels: a much more general method of investigation is needed.—MA.

2.3.9

**Technique of Replica Preparation for the Electron-Microscope Study of Surfaces and the Measurement of Surface Roughness.** ROBERT SEELIGER. *Metalloberflache* (A), 3, No. 10, 181-186 (1949).

Seeliger describes, in some detail: 1) a suitable type of replica-supporting grid, in which eight replicas can be mounted, and the use thereof; 2) various replica techniques—oxide film, plastic, condensation of metal or quartz layers from a vapor phase, aluminum foil impressions and double-layers; and 3) the boundary-shadow-casting technique for increasing the contrast of the surface elevations and depressions of the replica, thus enabling the roughness of the surface to be determined more exactly.—MA

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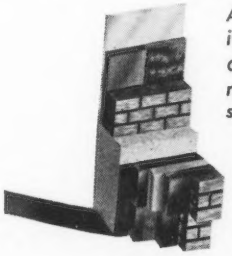

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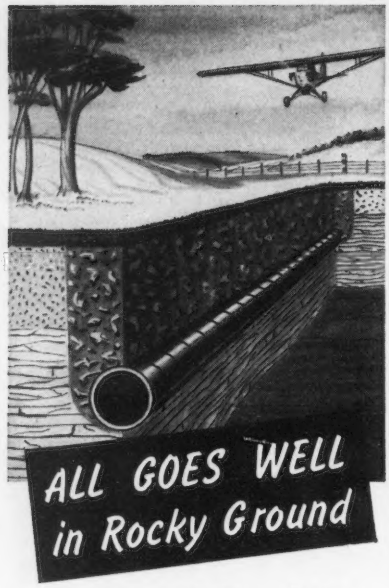


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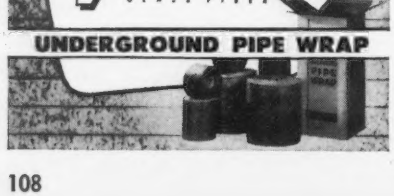

2.3.9

**The Electron Microscope and Its Applications in Metallurgy.** ADRIEN SAULNIER. *Rev. Aluminum,* **160,** 355-360 (1949).

After a short description of the electrostatic electron microscope and the techniques of specimen preparation, Saulnier describes a number of electronmicrographs showng the structure of an aluminum—4 percent copper alloy.—MA.

## 2.4 Instrumentation

2.4.3

**Summarized Proceedings of Symposium on Application of Ultrasonics.** Held by the Acoustics Group of the Physical Society, London, Feb. 1949. G. BRADFIELD. *Proc. Phys. Soc.,* B, **63,** No. 5, 305-322 (1950).

Several of the papers presented reported investigations of metallurgical interest. D. O. Sproule described a commercial flaw detector. He emphasized the importance of either having plane surfaces on specimens or else using shaped probes. An amalgam film between probe and specimen helped when rough asrolled surfaces had to be used unmachined. With good technique it was possible to determine the shapes of large flaws. G. T. Harris described the successful use of flaw-detecting apparatus for routine checking of large forgings of austenitic alloy steel, the surfaces of which were machined for the purpose. Though the forgings were 6 in. thick, porosity or defects of 0.5 mm in size or even less could be detected but a single defect could not be distinguished from a group of pinholes. W. C. Heselwood said that hairline and lamination cracks in steel could be detected by ultrasonics; routine inspection of rolls was so reliable that there were no failures in service: H. W. Taylor summarized experience in routine testing of aluminum alloy extrusions and casting billets; square extrusion sections were more amenable to flaw detection than round sections. Several speakers mentioned difficulties experienced with castings; columnar crystals might canalize the rays, while widespread porosity and "looseness" in ingots gave results difficult to interpret. Coarse defects were more easily detected and this was particularly useful with billets intended for extrusion. A different application to casting was described by A. N. Turner, who was able to effect marked grain refinement in castings of several aluminum alloys by ultrasonic vibration during slow freezing. This treatment also caused degassing, as efficiently as treatment with chlorine. Unfortunately, these advantages were often associated with enhanced macrosegregation, for instance in aluminum-silicon alloys. C. R. Maguire described a method for easy "tinning" of aluminum, particularly in the form of fine wires, by immersing for a short time in a molten globulc of 70:30 tin-zinc solder, subjected to ultrasonic vibration. In summarizing, G. Bradfield emphasized the particular value of ultrasonics for effecting irreversible actions, such as grain refinement and destruction of oxide films.—MA.

2.4.3

**Dye Method Reveals Metal Flaws.** *Aviation Week,* **53,** No. 3, 37 (1950).

Dy-Chek is a metal-inspection process by which microscopic cracks or flaws in metal can be detected simply, inexpensively, and accurately. The process is applicable to both ferrous and non-ferrous metals. An experienced user of the process can estimate the size and probable depth of the defect in a part without completely disassembling the engine or other equipment.

A patented, nontoxic, noncorrosive red dye is applied to the surface of the part under inspection, allowed to dry for 5 minutes, then wiped off with a special surface cleaner and dye remover. A white 'developer' solution is then applied. Any opening in the surface will be marked by fine red lines or dots as the dye, which possesses high capillary action, is drawn out by the developer. The lines or dots will remain until removed with cleaner.—PDA.

2.4.3

**Radiographic Testing of Filled Plastics.** F. B. SHAW, JR. Army Chemical Center. *Modern Plastics,* 28, No. 3, 123+ (1950) Nov.

It is proposed that radiography affords an accurate and rapid means of determining the concentration of pigments, fibers, or fillers in plastics in those common cases where these items are inorganic in nature. This approach would be particularly advantageous in the case of glass-fiber reinforced polyesters which are now in such common use and which are difficult to anlyze by the destructive method because of the insolubility of the resin. Not only does radiographic testing supply a rapid and accurate method of determining the quantity and distribution of inorganic pigments, fillers and fibers in organic plastics, but also its nondestructive nature makes more extensive testing of manufactured articles feasible and, therefore, makes possible higher and more uniform quality in the product.—TDD.

2.4.3

**Measurement of Thickness of Nonmagnetic Coatings.** (In Russian.) L. F. KULIKOVSKII AND A. M. MELIK-SHAKHNAZAROV. *Elektrichestvo* (Electricity), 1950, 67-70, Aug.

Describes apparatus for direct measurement of thickness of nonmagnetic coatings on magnetic bases. Includes theoretical explanation of the mechanism of the device.—BLR.

2.4.3

**Detection of Defects by the Luminescent Method in the Metal Industry.** M. M. LAUSHKINA AND F. I. ROGOV. *Izvest. Akad. Nauk SSSR,* Seriya Fizicheskaya, **13,** 251-253 (1949).

Report on the applications of the fluorescent penetrant method in the metal-founding and metal-working industries. Practical examples of the usefulness of the method including shrinkage cracks in aluminum, magnesium, or cobalt alloy castings, quenching cracks in steel, austenitic steel castings, and metal parts of complex shape not amenable to radiography are given. The intensity of fluorescence as a function of depth of defect, nonmetallic inclusions, products of corrosion and defects which cannot be detected by the fluorescent penetrant method are discussed.—INCO.

2.4.2

**Instruments for Paint Performance**

Tests. *Product Finishing*, **3**, No. 6, 53-68; No. 7, 76-82 (1950).

This review describes instruments for the following tests: film thickness (dry), hardness, scratch-hardness, flexibility and adhesion, impact resistance, abrasion resistance, accelerated weathering; where available, suppliers' names are mentioned. Two rotational viscometers, a mobilometer and a self-contained weatherometer unit are described.—RPI.

2.4.3

**Advances in Non-Destructive Materials Testing by Means of Ultrasonics.** (In German.) OTTO RUDIGER. *Stahl u. Eisen*, **70**, 561-565, (1950) June 22; condensation *Engr's Digest*, **11**, 352-354 (1950) Oct.

Describes and diagrams the four elements (intensity, image, reflectoscope, and resonance) of the above method, especially useful detecting cracks, piping, and weld defects, measuring wall thicknesses, etc. Diagrams, X-ray patterns, and graphs.—BLR.

2.4.3

**Magnetic and Inductive Non-Destructive Testing of Metals.** I. R. ROBINSON. *Metal Treatment*, **16**, No. 57, 12-24 (1949).

Robinson discusses the theoretical and general aspects of the eddy-current and ferrographic methods of non-destructive testing. Details of apparatus are given, together with a discussion of their capabilities.—MA.

2.4.3

**Quick Inspection Method for Engine Parts.** REBECCA H. SMITH. *Automotive Ind.*, **102**, No. 9, 46-47, 90 (1950).

Smith discusses the importance of a non-destructive test that can be applied while components are still on the test-bed. The indications show the presence of very small cracks before they have grown to serious dimensions. The test uses the principle of dye penetration. The dye gives a vivid indication of the penetration of the oil into any cracks. The procedure is described in detail and the types of flaws indicated by the test are listed. The test has been employed on anodized and plain aluminum, stainless steel, carbon steels, nickel alloys, magnesium and copper alloys and on hard-facing materials.—MA.

## 3. CHARACTERISTIC CORROSION PHENOMENA

### 3.2 Forms

3.2.2

**Diffusion of Gases in Metals. Case of the Iron-Hydrogen System.** (In French.) PAUL BASTIEN. *Metaux & Corrosion*, **25**, 248-262 (1950) Oct.

Presents a comprehensive theoretical review of the above problem. Analyzes the adsorption of gas by metals, diffusion of gas into metals, permeability of iron toward hydrogen, and solubility of gases in metals. Numerous tables and graphs.—BLR.

3.2.2, 6.2.3

**Hydrogen Embrittlement of SAE 1020 Steel.** J. B. SEABROOK, N. J. GRANT, AND DENNIS CARNEY. *J. Metals*, **188**, 1317-1321 (1950) Nov.

Hot-rolled SAE-1020 machined into


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tensile-test bars was cathodically charged with hydrogen. Vacuum tin-fusion analysis provided accurate values of hydrogen. True stress-true strain tensile tests with and without aging of the test bars and at various strain rates indicate the role of hydrogen as an embrittling agent.—BLR.

3.2.2, 7.6.4

**Hydrogen Embrittles Steel.** C. A. ZAPFFE. *Research Reviews*, **1950**, 1-6, Nov.

Hydrogen, caused by water vapor resulting either from steam or humidity in the air, has damaging effect on both alloys and steam boilers. In alloys, hydrogen absorption during casting is responsible for inferior strength; in steam boilers, brittleness severe enough to cause dangerous explosions has resulted. This article reports the results of a study to determine the exact effects of hydrogen on steel. Type 410 steel, which was allowed to age for two months, had a certain amount of embrittlement immediately after hardening. This was followed by a slight increase in embrittlement as hydrogen atoms continued to precipitate from the lattice into the voids. When the precipitating action dissipated itself, the brittleness decreased noticeably as the gas exploded its way from pocket to pocket and finally diffused itself to the surface where it escaped.—TDD.

3.2.2, 6.3.6, 1.3

**A Brief Survey of Stress and Corrosion Cracking in Brass.** R. STETTLER. *Sheet Metal Ind.*, **27**, No. 274, 119-122 (1950). (Translated from *Pro-Metal.* June 1949.)

Stettler summarizes the present knowledge of season-cracking phenomenon, and concludes that cases of stress-corrosion of brass are comparatively few.—MA.

3.2.2, 3.6.1

**Evans Cells: A Reply to Masing's Remark on the Theory of Corrosion by Local Currents.** (In German.) K. WICKERT AND H. WIEHR. *Werkstoffe u. Korrosion*, **1**, 299-302 (1950) Aug.

Describes a few experiments, which prove that Masing and Evans' opinions can be experimentally disproved even when Evans cells with low electrolytic and external resistance are used. Evans' experimental results are said to be valid only when reactivity of the electrode surfaces is considered.—BLR.

3.2.2

**Reversible Hydrogen Brittleness of Iron and Steel at Low Temperatures.** P. BASTIEN AND P. AZOU. *Compt. Rend.*, **229**, No. 11, 549-551 (1949).

Discovery of existence of a distinct reversibility of brittleness induced in steel by hydrogen. Temperature range within which this reversible brittleness manifests itself. Authors' explanation of phenomenon; cold working as a factor secondary to hydrogen pressures and triaxial stresses. Translation available Henry Brutcher, Box 157, Altadena, Calif.

3.2.3, 6.3.19

**A Typical Case of Intercrystalline Corrosion in the Ageing of a Zinc Alloy** (In Italian.) *Montevecchio* (Italy), **1**, No. 4, 6-9 (1950) Dec. 10 Illus. 1000 Words.

An account of a case of intercrystalline corrosion arising in a zinc alloy die cast lock which was badly contaminated with tin and lead. The lock had been cast in 1940 and used under normal atmosperhic conditions; the failure was reported recently. The phenomenon of intercrystalline corrosion is described in some detail, and illustrated by photomicrographs, which are contrasted with others of sound specimens. It is explained that while intercrystalline corrosion is accelerated by moisture, heat, mechanical stressing, etc., it will appear ultimately on simple ageing in castings which are contaminated.—ZDA.

3.2.3, 3.5.9, 3.4.6, 6.2.2

**The Oxidation of Pure Iron.** J. K. STANLEY, J. VON HOENS, Westinghouse Research Labs., and R. T. HUNTOON, Carnegie Inst. Tech. Paper before ASM. 32nd Ann. Conv., Chicago, Oct. 23-27, 1950. Am. Soc. Metals, 1950, Preprint No. 5, 21 pp.

The oxidation of high-purity electrolytic iron (Puron) in air from 500°-900°C proceeds by the common parabolic rate law, $W^2 = Kt + C$. The oxidation process as a function of temperature follows the usual exponential law. The rate constant, K, shows the temperature dependence $K = 0.37\ e^{-33,000/RT}$. A Geiger counter X-ray spectrometer showed only one oxide, ferroso-ferric oxide ($Fe_3O_4$), about 500°C, but 3 oxides $\alpha$-ferric oxide ($Fe_2O_3$), ferroso-ferric oxide ($Fe_3O_4$) and ferrous oxide (FeO) at the higher temperatures. Metallographic examination resolved the various oxide strata. Ferrous Oxide (FeO) could be cooled to room temperature without decomposition to iron and ferroso-ferric oxide ($Fe_3O_4$). Photomicrographs show typical structures. Tables and graphs are included.—INCO.

3.2.3, 6.3.6

**Low-Temperature Oxidation of Copper. I—Physical Mechanism.** T. N. RHODIN, JR. *J. Amer. Chem. Soc.*, **72**, No. 11, 5102-5106 (1950).

In a systematic study of the low-temperature oxidation characteristics of single-crystal faces of copper in the temperature range 78°-335° K., the growth of very thin oxide films was followed with an accuracy of 2 percent by determination of actual surface areas from micro-adsorption isotherms obtained by a microbalance technique. The rate equation $dx/dt = A \exp(x_1/x - W/kT)$, where x is the film thickness at time t, $x_1$ a critical film thickness, W the energy of activation, and A a temperature independent constant, derived from the hypothesis of Cabrera and Mott (*Rep. Progress Physics*, **12**, 163 1948-1949); *Met. Abs.*, **17**, 422 (1949-1950), was found to be valid with some limitations for film thickness in the range 5-50 Å. and temperatures of 78°-300° K. Limitations of the hypothesis are discussed.—MA.

3.2.3, 6.4.2

**Concerning Structure of the Oxide Formed on an Aluminum Surface.** (In Russian.) M. S. BELETSKII. *Doklady Akademii Nauk SSSR* (Reports of the Academy of Sciences of the USSR), new ser., **75**, 551-553 (1950) Dec. 1.

The above was experimentally investigated. Assumptions of Trillat, Brandenburger, and others, that the oxide surface layer of aluminum consists of $\gamma$-aluminum oxide and bemite is challenged. Results of investigation showed that bemite ($Al_2O_3.H_2O$) does not form during the oxidation of aluminum, but is the product of a secondary reaction taking place between water and dispersed aluminum oxide ($Al_2O_3$) present on the surface. Method of investigation is described. Data are tabulated. —BLR.

3.2.3, 4.3.5, 4.4.6

**The Mechanism of the Reaction Between Silver and Sulfur in Mineral Oil.** R. T. FOLEY, W. MORRILL, AND S. J. WINSLOW. *J. Phys. Colloid Chem.*, **54**, 1281-1292 (1950) Dec.

Presents results of experimental and theoretical study of the above. Purpose of the investigation was to break down the total tarnishing process into its consecutive steps and to evaluate each step both theoretically and experimentally. Data on effects of various factors on the sulfiding rate, including effects of a variety of added compounds, are tabulated and charted. 15 references.—BLR.

## 3.3 Biological Effects

3.3.2

**Fouling of Ships and Practical Means of Determining the Condition of Their Bottoms and Its Effect on the Economy of Operation.** M. GAUTIER. *Bull. Tech. Bur. Veritas*, **32**, 171 (1950); *J. Brit. Shipbuilding R. A.*, **5**, No. 9, 534-535 (1950).

An article on the assessment of the incidence and economic importance of fouling. Orthodox toxic paints are probably superior to the newer plastic type. —RPI.

3.3.2

**Electrical Control of Marine Fouling.** E. S. CASTLE. *Ind. & Eng. Chem.*, **43**, 901-904 (1951) April.

Data show that marine fouling can be prevented on steel plates in sea water which are cathodes in a galvanic circuit, if current densities above 1000 milliamperes per sq. ft. are maintained. This effect is primarily due to the rapid peeling off of deposits formed on the cathode by electrolysis of sea water, these layers carrying off with them any attached growth of barnacles. In addition, cathodic products of electrolysis in solution within short distances of the electrode appear to be unfavorable for growth of fouling organisms.

3.3.3

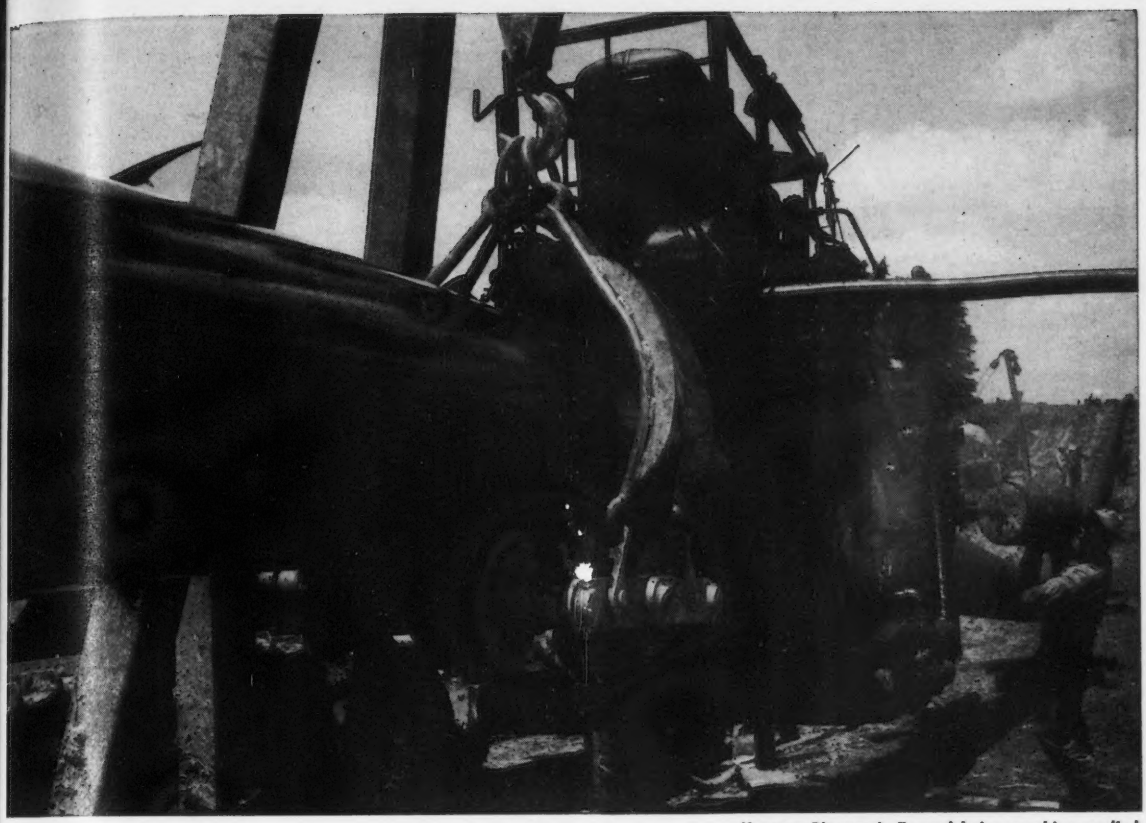
**Effectiveness of Copper Naphthenate Surface Treatments in Preventing Marine Borer Attack.** M. GOLL. Anodic Products, Pamphlet, 1948, June, 4 pp.

Wood treated by cold soaking or brushing with copper naphthenate solutions showed no evidence of attack after being immersed in sea-water for 7 months. Tests on Eastern white pine showed that two brush coats of the 2 percent solution gives approximately the same retention as a 16-hour soak in the same solution.—RPI.

3.3.4, 5.8.2

**Corrosive Effects of Fungicides.** ORR 185/49 (PB. 4088); *Rev. Current Lit Paint Colour Varnish Allied Inds.*, **23**, No. 134, 192 (1950) March-April. (Seen in abstract form only.)

Whereas copper naphthenate used as a fungicide on textiles may accelerate the corrosion of aluminum or zinc with which they are in contact at high humidity, zinc naphthenate inhibits corrosion of aluminum, zinc and steel.—ZDA.



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3.4.6, 2.3.9, 3.5.9, 6.5

**The Oxidation of Several Metals in Activated Oxygen at High Temperatures.** A. DRAVNIEKS. *J. Am. Chem. Soc.*, **72**, No. 8, 3761-3767 (1950) Aug.

The oxidation of copper and tantalum, zirconium, molybdenum and nickel in ordinary and in activated oxygen are compared. Only in the case of copper are reproducible differences caused by the presence of an excess of free oxygen atoms in oxygen. Cases in which the monatomic oxygen accelerates, retards or does not influence the rate of oxidation are described. The conditions for the appearance of cupric oxide in the scale are outlined and an explanation of some types of complex oxidation curves is attempted. Apparatus and procedure are described and diagrammed; data are tabulated and charted.—INCO.

3.4.8, 4.6.11, 8.9.5

**Tests on Painted Sub-Marine Structures.** G. DECHAUX. *Ossature Metallique*, **14**, 565-574 (1949); Dec.; *J. Iron Steel Inst.*, **165**, Pt. 3, 356 (1950).

A discussion is presented on the prevention by painting of the corrosion of metals, in particular ships' keels, which are partially or totally submerged in sea water. Protection of immersed surfaces against fouling is also considered.—RPI.

3.4.9, 4.4.2

**Effect of Water on the Interaction Between Benzene Solutions of Palmitic Acid and Metal Oxides.** J. K. LANCASTER AND R. L. ROUSE. *Research*, **4**, 44-46 (1951) Jan.

Tingle recently showed that freshly formed metal-oxide surfaces require treatment with water before they will react with a fatty acid. The water treatment varies from metal to metal. Experiments described were planned to discover whether by use of very dry conditions, chemical reaction would be prevented. Heat changes accompanying the interaction between the fatty acid solution and the powder were followed by means of a calorimeter. Results indicate that reaction rate between a metal oxide and a fatty acid depends on amount of water present; and drops to zero if water is absent.—BLR.

## 3.5 Physical and Mechanical Effects

3.5.3

**Cavitation in Liquids.** E. G. RICHARDSON. *Endeavour*, **9**, 149-153 (1950) July.

Summarizes (with excellent illustrations) knowledge of the above, which plays a part, for example, in the design of ships' propellers, in the study of certain types of metallic corrosion and in the application of some ultrasonic techniques.—BLR.

3.5.5, 3.2.3

**The Role of Diffusion in Surface Oxidation of Metals.** (In French.) J. BENARD. *Metaux & Corrosion*, **25**, 241-247 (1950) Oct.

The above was investigated for various metals whose density is greater than that of their respective oxides. Kinetics of metal oxidation, mechanism of diffusion in the oxide film, microscopic structure of the oxide film and influence of the metal-oxide interface on rate of diffusion were emphasized. Data are tabulated and charted.—BLR.

3.5.8, 5.8.2

**Effectiveness of Molybdenum Disulfide as A Fretting-Corrosion Inhibitor.** D. GODFREY AND E. E. BISSON. Lewis Flight Propulsion Lab. National Advisory Com. Aeronautics, Tech Note 2180, 27 pp. (1950) Sept.

Six methods of applying molybdenum disulfide to steel as a fretting-corrosion inhibitor were evaluated. Inhibitor action between steel balls vibrating in contact with glass flats was microscopically observed; number of cycles required to produce incipient fretting corrosion was noted. Experiments with steel flats vibrating in contact with steel flats were also conducted. A bonded molybdenum disulfide delayed fretting corrosion for 28,000,000 cycles for steel against glass at about 10,000,000 cycles for steel against steel. Dry molybdenum disulfide and mixtures with water, oil, or grease appreciably delayed fretting corrosion. Without an inhibitor, specimens fretted immediately. Effectiveness of any inhibitor is dependent on its ability to prevent metallic adhesion continuously.—INCO.

3.5.8

**X-Ray Investigations of the Behaviour of Materials (Steels and Duralumin) Under Alternating Stresses.** A. SCHAAL. *Z. Metallkunde* (Germany), **40**, No. 11, 417-427 (1949).

X-ray determinations were made of the internal (residual) stresses arising from the application of slow and rapid cyclic tensile and compressive stresses in three alloy steels and a Duralumin alloy, all of which had been fully annealed. The results show that: 1) fatigue testing produces greater internal stresses, of a compressive nature, than does simple tensile or compression testing, 2) the internal stresses produced by fatigue tests on material which has been prestressed after annealing, are smaller than those produced in material which has only been annealed; when the prestress is tensile the internal stresses are compressive, and vice versa, and 3) fundamentally, Duralumin has fatigue properties similar to those of the alloy steels.—ALL.

3.5.8, 6.2.3, 3.4.8

**Influence of Surface-Active Substances on Fatigue Strength of Steel.** (In Russian.) G. V. KARPENKO. *Doklady Akademii Nauk SSSR* (Reports of the Academy of Sciences of the USSR), new ser., **73**, 1225-1228 (1950) Aug. 21.

Two steels (20X and 40X) subjected to different heat treatments were investigated during contact with the following media: air, water, 2 percent amyl alcohol in water, lubricating oil + 2 percent oleic acid and castor oil + 2 percent linoleic acid. Data are charted and discussed.—BLR.

3.5.8, 3.5.9

**Metals and their Resistance to Heat.** (In Italian.) G. CARRO-CAO. *L'Aerotecnica*, **30**, No. 3, 120-131 (1950) June 15.

Creep and fatigue properties required of materials used in gas turbines; mechanism of deformation, ageing, recrystallisation; effect of different elements on these processes; creep (mathematical treatment and influencing factors); fatigue and corrosion-fatigue; outline of principles of creep and fatigue testing. —BNF.

3.5.8, 1.3

**Corrosion-Fatigue of Metals—A Critical Survey.** A. J. GOULD. *Iron and Steel*, **24**, 7-10 (1951) Jan.

The phenomenon, methods of test, characteristics of corrosion-fatigue, influence of concentration of the corrosive solution and its nature, and means for reducing severity by arrangement of parts to avoid or minimize contact with corrodents, improved design, corrosion-resisting materials, protective coatings, corrosion inhibitors, emulsifying oils, cathodic protecting currents and shot peening are discussed. 20 references.—INCO.

3.5.8

**Fretting Corrosion.** G. FONTANA. *Metaux & Corrosion*, **25**, 299-300 (1950) July/Aug.—MI.

3.5.8, 3.7.3, 6.2.3

**Static Failure and Fatigue of Steels With Particular Reference to Welded Structures.** M. ROS. *Sheet Metal Industries*, **26**, 2417-2426+ (1949) Nov.; 2625-2656+ (1949) Dec.

Presents details of theories proposed by Laboratoire Federal d'Essai des Materiaux, Zurich, Switzerland, to explain the above. Concluding installment presents extensive theoretical discussion and results of confirmatory experiments. Numerous diagrams, graphs, tables, macrographs and photoelastic stress patterns are presented; appearance of several fatigue fractures is illustrated and discussed.—BLR.

3.5.8, 8.9.1, 2.3.7

**Fretting Corrosion in Aircraft and Aircraft Accessories.** A. E. RAHM AND H. J. WURSTER. Wright-Patterson Air Force Base, Dayton, O. Paper, A.S.L.E. 5th Annual Conv., Detroit, April 12, 1950. *Lubrication Eng.*, **7**, No. 1, 22-23+ (1951) Feb.

"Fretting corrosion" or "friction oxidation" has been defined as the rapid corrosion that occurs between contacting metal surfaces when subjected to slight relative (vibrating) motions. Prior work on the solution to this problem is reviewed briefly and research reported on a study of the process in the presence of various design factors, surface, finishes and lubrication provisions. Tabulated results of tests on several different types of surface finishes and certain selected AN lubricants are given which indicate that neither greases, surface finish nor design factors as such represent a solution to the problem of friction oxidation. It is suggested however that a combination of the best factors of all three may result in a substantial increase of operational life time of grease lubricated bearings and component parts in aircraft and aircraft accessories. It is hoped that a more extensive program now planned may ascertain the most beneficial combination and permit setting a specification for the best surface and AN lubricant for this purpose. 16 references.

3.5.9, 6.5

**Properties of Metals at Elevated Temperatures.** G. V. SMITH. *Mech. Eng.*, **72**, 799-804 (1950) Oct.

Briefly surveys the above, which are classified in the broad categories: strength; other physical properties such as thermal expansivity or conductivity, elastic moduli, and the like; resistance to scaling or other corrosive attack; and changes in

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microstructure occurring during service, and effect of these on properties. Graphs and photomicrographs.—BLR.

**3.5.9, 6.2.5, 6.3.10**

**Heat Resisting Steels and Alloys.** *Aciers Fins & Speciaux,* **1950,** No. 6, 32-34, Nov.

Qualities required and formulas for heat resisting steels of the chromium-nickel type. Superficial modifications, structural and dimensional stability, ferritic alloys, austenitic alloys rich in chromium and nickel, and refractory alloys which are tenacious under heat are discussed. Alloys with a high nickel content have a high resistance to shock and do not cause brittleness. The ATV alloy (35 nickel, 11 chromium) was the first solution to cracking corrosion in vapor. The ferritic alloys (12, 18 or 28 chromium) cannot be regenerated for they lose their ductility and become brittle. The austenitic alloys (13-30 chromium and 10-20 nickel) can normally receive additions of W which improve their resistance to oxidation. The 60 nickel-12 chromium alloy is resistant to reductive atmospheres, carburizing, nitriding or alkaline vapors. It contains little iron and can be used up to 1150-1200°. Its high resistivity and resistance to alternating heating and cooling and thermal shock makes it applicable for use as electric resistances. Where creep resistance is desired, super refractory alloys are used. They are derived from the groups of austenitic alloys rich in nickel and chromium. They contain 12-77 nickel, 13-20 chromium, 10-20 cobalt, 3-5 wolfram (tungsten) and additions of molybdenum, titanium, columbium and aluminum.—INCO.

**3.5.9, 4.3.3, 6.2.5**

**Untersuchungen Uber den Angriff Vanadiumhaltiger Oelaschen auf Hitzebestandige Stahle.** P. Amgwerd. Ph.D. Thesis, Technischen Hochschule, Zurich, 1949. Genossenschaftsdruckerei, Zurich, 1949. 51 pp. (TA-467, A-51).

This action of vanadium-containing fuel oil ashes on heat resistant steels was investigated in the temperature range from 650°-850° C. The vanadium-containing ashes accelerated the scaling of all heat resistant steels investigated, when the temperature was above the melting point of the ash. The attack increased with rising temperatures, quantity of reacting material and time of exposure. The alkali content of the ash also influenced the extent of the attack. The vanadium compounds appear to act as oxygen carriers. The corrosive action of the ash was particularly severe on molybdenum containing steels.

**3.5.12**

**The Nature of Friction: The Phenomena of Wear and Boundary Lubrication.** H. Brian Locke. *Metal Ind.,* **77,** No. 25, 303-305; No. 26, 323-324 (1950).

Locke discusses the nature of surfaces, the examination of asperity, the mechanism of friction, and the theory of bearing metals. Boundary lubrication is brought about by films of molecules adsorbed on or combined with surfaces in contact. It occurs at all surfaces except those especially cleaned and outgassed, and is difficult to remove. It inhibits pressure welding, but is of use in everyday affairs. Locke shows that since "dirt" is enough to cause partial lubrication, there may be an entirely unintentional effect that, although usually unavoidable, is commonly beneficent and normally amendable to improvement. 25 references.—MA.

## 3.6 Electrochemical Effects

**3.6.2, 6.2.5**

**Pit or Cavity-Corrosion of High Chromium Stainless Iron Caused by Contact with Non-Conductive Substances and Its Prevention.** H. Endo. *Science Reports of Res. Inst. Tohoku Univ.,* **1,** Series A, No. 4, 349-356 (1949) Dec.

In an acidic oxidizing solution containing chloride ions, the entire surface of 14 chromium stainless iron or steel corrodes, whereas that of 21-35 chromium stainless iron, does not. When the surface of this high chromium stainless iron comes in contact with non-conductive substances such as glass, cork or rubber, or with noble metals like platinum and gold, a narrow crevice acting as a capillary is formed and the corrosion takes place in the pit or cavity at the point of contact. Two specimens of 22 chromium, 22 chromium-3 molybdenum, 22 chromium-7 molybdenum, and 35 chromium stainless iron, 1 annealed at 900° C and the other quenched in water from 1,090 or 1,300° C, were tested in 5 ferric chloride aqueous solution to determine whether pit or cavity corrosion takes place. The mechanism is discussed. 22 chomium stainless iron is affected by the contact, but this effect is greatly reduced when it is alloyed with 7 molybdenum and quenched in water. The contact effect is reversed for 35 chromium stainless iron. The surface of the annealed specimen is not subject to cavity corrosion, but the quenched one is. The method of prevention of the contact effect is discussed. Illustrated.—INCO.

**3.6.5, 6.3.8**

**Potential-pH Diagram of Lead and Its Applications to the Study of Lead Corrosion and to the Lead Storage Battery.** P. Delahay, M. Pourbaix, and Pierre Van Rysselberghe. Paper before Electrochem. Soc., Buffalo, Oct. 11-13, 1950; *J. Electrochem. Soc.,* **73,** No. 2, 57-64 (1951) Feb.

The reactions and equilibrium equations of the system lead-water are given in detail and are used in the construction of the potential-pH diagram of lead. Some important features of the diagram are discussed, in particular the solubilities of oxides and hydroxides and some of the important oxidation reduction reactions. A modified form of the potential-pH diagram of lead showing corrosion, passivity and passivation domains is presented. The addition of passivation domains due to the presence of carbon dioxide and carbonates are determined. A modified potential-pH diagram taking into account the presence of sulfate in solution is also presented. Important features of the behavior of lead storage batteries are studied on the basis of this modified diagram.—INCO.

**3.6.5, 2.3.5, 6.3.2**

**Potential of Cadmium in Sulphuric Acid.** J. M. Roxburgh and C. A. Winkler. *Can. J. Research,* (B), **28,** No. 7, 391-394 (1950).

Roxburgh and Winkler describe experiments made to find out why the potentials determined for mechanically cleaned cadmium electrodes in air-free sulfuric acid were less negative than those reported by Gatty and Spooner ("The Electrode Potential Behaviour of Corroding Metals in Aqueous Solutions," 1938) for electrodeposited electrodes. The potentials of various mechanically cleaned cadmium electrodes were measured relative to a calomel electrode. The electrolyte was 0.2 N air-free sulfuric acid; in one experiment N air-free potassium chloride was used. A freshly scraped cadmium surface gave a potential of —0.753 V., compared with —0.81 V. reported by Gatty and Spooner for a deposited electrode. It is concluded that the physical condition of the electrode affects the potential.—MA.

**3.6.5**

**Electrolytic Corrosion of Metals.** A. E. Durkin. General Electric Co. *Gen. Elec. Rev.,* **54,** No. 2, 45-48 (1951) Feb.

When designing new equipment, important consideration should be given to the selection of such materials so that the part will operate in service without being adversely affected by ordinary corrosive atmospheres. If dissimilar metals are used in the design and the part is operated in or even subjected to the atmosphere, there is a possibility that localized pitting and corrosion will result. This condition is known as electrolytic corrosion and is governed largely by the positions of the materials in what is called the Electromotive Series. This series lists the order in which elements and metals can replace others from solution. When any two dissimilar metals in this series are in contact in a suitable electrolyte, a cell is set up in which the metal that is higher in the series is the negative pole and the lower one the positive pole. The farther apart the metals are in the series, the greater the potential differences between them and the higher the corrosion rate. The Electromotive Series, which is shown in tabular form, was compiled to include the common types of alloys as well as the metals from which engineering groups must select materials for the design and manufacture of their products. This table is not absolute, but it is a guide in determining how safely two metals can be used in contact with each other.—TDD.

**3.6.5, 6.3.11**

**Potential-pH Diagram of Silver; Construction of the Diagram—Its Applications to the Study of the Properties of the Metal, Its Compounds, and Its Corrosion.** Paul Delahay, Marcel Pourbaix, and Pierre Van Rysselberghe. *J. Electrochem. Soc.,* **98,** 65-67 (1951) Feb.

On the basis of methods and conventions previously described, and using the available thermodynamic and electrochemical data, the above diagram was constructed. A derived diagram showing domains of corrosion, passivity and passivation is also presented.—BLR.

**3.6.5, 5.4.5, 4.6.11**

**Electrical Properties of Paint Films on Steel in Sea-Water.** K. N. Barnard and J. H. Greenblatt. *Chem. Canada,* **1,** 37 (1949).

Painted steel is cathodic to bare steel. The older the paint film, the greater is the amount of current which passes. The behavior of various commercial paints is discussed.—RPI.

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3.6.6, 3.8.2, 4.4.6, 4.4.2

**Activity of Galvanic Cells and Electrochemical Corrosion of Metals by Dielectrics.** (In Russian.) L. G. GINDIN. *Doklady Akademii Nauk SSSR* (Reports of the Academy of Sciences of the USSR), **74**, 311-313 (1950) Sept. 11.

Results of experimental investigation indicate that an ordinary galvanic magnesium-iron cell generates an electric current in a 1.5N acetic acid in isooctane solution. Methods of investigation and results of measurement of emf are described. The above phenomenon indicates that rate of corrosion of metals in dielectrics is determined not so much by their electro-conductivity as by solubility of the corrosion products.—BLR.

3.6.6, 7.2, 8.9.3

**The Fundamentals of Galvanic Corrosion.** A. B. LAUDERBAUGH. Manuf. Light & Heat Co. Paper before Canadian Gas Assoc., Quebec, June 20-23, 1950. *Oil Gas J.*, **49**, No. 15, 97-98+ (1950) Aug. 17.

The author presents some fundamentals of galvanic corrosion in oil and gas pipe lines. For a steel pipe, moist earth becomes the electrolyte, two areas on the surface of the pipe are the two electrodes and the pipe wall completes the circuit. This set up is a galvanic cell and the area of the pipe becoming the anode will corrode. This action will be produced in the presence of metallic and electrolytic dissimilarities. Some of these galvanic cells can be counteracted by using impressed current, installing expendable anodes (aluminum, zinc and magnesium) or by using pipe coatings having an electrical insulating value. Illustrations.—INCO.

3.6.10, 6.2.3

**Migration of Carbon in Steel Under the Influence of Direct Current.** *J. Metals*, **188**, No. 9, 1156-1158 (1950) Sept.

## 3.7 Metallurgical Effects

3.7.1, 8.4.3

**Corrosion.** M. G. FONTANA. *Ind. & Eng. Chem.*, **43**, No. 2, 63A-64A (1951) Feb.

Structures of steel and cast iron which are present at different carbon contents and temperatures. The addition of 8 nickel to steels with over 0.8 carbon permits the retention austenite to below room temperature and transformation does not occur upon cooling. In oil well service and some sulfuric applications, the structure of the steel has a marked effect on the rate of corrosion. In ringworm corrosion of oil well tubing, examination showed that the good material consisted of the lamellar structure. The metal that corroded was partially spheroidized pearlite caused by heat treatment (photographs of structures given).—INCO.

3.7.2, 2.3.2, 6.3.8

**A Rapid Method for Control of Quality of Metallurgical Lead.** (In Czech.) JAN KALOC. *Hutnicke Listy*, **5**, 450-453 (1950) Nov.

Effect of small amounts of impurities on corrosion resistance of lead to various chemicals is discussed and two methods for rapid quality control are described: determination of "breakdown" point in sulfuric acid; and an aqua regia test. Dependence of breakdown point on quantity and type of impurity was tested using lead of less than 99.99 percent purity. Results are tabulated, charted and illustrated.—BLR.

3.7.3

**Effect of Alloying Additions on Hydrogen Diffusion Into Iron and a Contribution to Knowledge Concerning the Iron-Hydrogen System.** (In German.) WERNER GELLER AND TAK-HO SUN. *Archiv fur das Eisenhuttenwesen*, **21**, 423-430 (1950) Nov.-Dec.

Reports results of experiments made with pure iron and 5 different steels to study effects of composition and temperature on the above. Iron-hydrogen constitution diagrams are presented and discussed. Data are graphed and tabulated. 33 references.—BLR.

3.7.3

**Some Observations on Underbead Cracking in Welding of High-Tensile Low-Allow Steel.** J. A. RINEBOLT AND J. O. MACK. U. S. Naval Research Laboratory. (Report M-3390) March 1949. vi. 27 p.

A test was developed for detecting and measuring cracks forming in the heat-affected zone under the bead of a weld, and an investigation was made of the effects of welding conditions and the chemical and physical properties of the weld material on the formation of cracks.

Cracking sensitivity increases as the carbon and manganese content and the hardenability of the steel increase. Cracks occur more and more frequently as the plate thickness is increased to about 1 in., but become less frequent at greater thicknesses.

There is no correlation between underbead cracking and tensile strength, hardness, or heat input within the ranges studied. Underbead cracking can be forestalled by preheating; the amount of cracking decreases with increasing temperature. The required preheating temperature varies, however, from steel to steel. For a given steel cracking increases with maximum underhead hardness, but the hardness level at which cracking can be eliminated also varies from steel to steel.

Cellulose-coated electrodes have the greatest underbead cracking tendency. By contrast, cracking does not occur at all with the 25-20 electrode and is less than 1 percent with the low-hydrogen electrode.

Test procedure is given.

The twelve different steels tested included ten high-tensile steels supplied by five different producers, a plain carbon (Navy Grade M) mild steel, and a 1.7 percent-nickel steel.—ZDA.

3.7.3, 6.2.3, 6.2.4

**The Effect of Cold-Work on Steel. Sec. V-An X-Ray Investigation of Structural Changes in Steel Due to Cold-Working.** D. V. WILSON. *J. Iron Steel Inst.*, **165**, Pt. 4, 376-381 (1950) Aug.

X-ray examinations on high carbon and alloy steels (one containing 3.43 nickel and one 15 chromium) after cold working by compression failed to reveal the presence of austenite in unfractured test pieces. It is shown, however, that austenite may be formed on the surface of shear fractures. An X-ray investigation of the influence of severe cold-working on cementite in steel (0.05 nickel) was made, and evidence of large residual strains in such cementite, together with some tendency towards preferred orientation was found. X-ray patterns are given.—INCO.

3.7.3, 6.5.2

**The Influence of Heat-Treatment on the Corrosion-Resistance of the Magnesium-Aluminium Alloy, Mg-A17.** W. BULIAN. *Werkstoffe u. Korrosion* (Germany), **1**, No. 1, 10-12 (1950).

A study was made of the corrosion-resistance of the magnesium-base alloy, Mg-A17, containing aluminum 7-8, zinc 1, and manganese 0.1 percent, to a 0.3 percent NaCl solution. Specimens of the alloy were extruded at 350° C (662° F) and tested: 1) as extruded and after ageing for 20 hr. at 200° C (392° F), and 2) after solution-treatment at 420° C (788° F) for 2 days, and with and without warm-ageing as above. The corrosion was determined by immersion of the specimen in the salt solution, and eudiometer measurements of the volume of hydrogen generated after periods of up to 240 hr. The results show that material having a homogeneous structure (directly after extrusion or solution-treatment, when the $Al_2Mg_3$ phase is held in solid solution) corrode much more rapidly than does material which has been subjected to warm-ageing and has, in consequence, a heterogeneous structure due to precipitation of $Al_2Mg_3$. Homogeneous material corrodes at a rate which increases almost logarithmically with time, and the rate is higher when the homogeneity is caused by solution-treatment. The results are compared with those of other workers.—MA.

3.7.3, 6.3.5, 6.4.2

**Stainless Steel Rivets Improve Joint Strengths in Aluminum.** ROY A. MILLER. Consolidated-Vultee Aircraft Corp., San Diego, Calif. *Product Eng.*, 21, No. 2, 112-116 (1950) Feb.

When stainless steel rivets are used to join aluminum alloy sheet, the wire for the rivets should be procured in the annealed condition, be of cold-heading quality, and contain 18-20 percent chromium, 8-10 percent nickel, and 0.06-0.12 percent carbon.

The rivets should be headed in a rivet machine without subsequent annealing but followed by sandblasting, pickling, and cadmium plating. They should be driven or upset to a flat head with a diameter 1-1/3 the shank diameter. The length of the extended shank from which the upset head is to be formed should be 1¼ to 1-1/3 the shank diameter. To relieve the upsetting loads for the larger rivets, a centered hole may be provided in the end of the shank, with a diameter ½ that of the shank and a depth of ⅝ the shank diameter.

The ultimate shear strength of a protruding head rivet will be at least 75,000 psi. When driven as a flush rivet, the shear strength will depend somewhat on the sheet thickness and strength. Tensile strength will be at least equal to its shear strength.

The rivets should be used at a minimum spacing of 3 diameters and a minimum edge distance of 2 diameters. It should not be used in brittle materials such as cast 195-T6 aluminum, nor as a protruding head rivet, nor as a machine countersunk rivet in aluminum alloy sheet less than 0.051-in. thick.

The corrosion resistance of joints in 75S-T6 aluminum will be satisfactory

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Ross-Meehan Foundries, Chattanooga 1, Tenn.
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Texaloy Foundry Co., San Antonio 3, Texas
Thomas Foundries, Inc., Birmingham 1, Alabama
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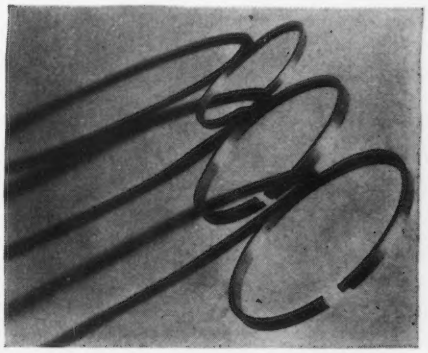
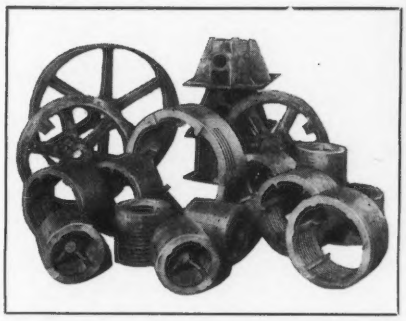
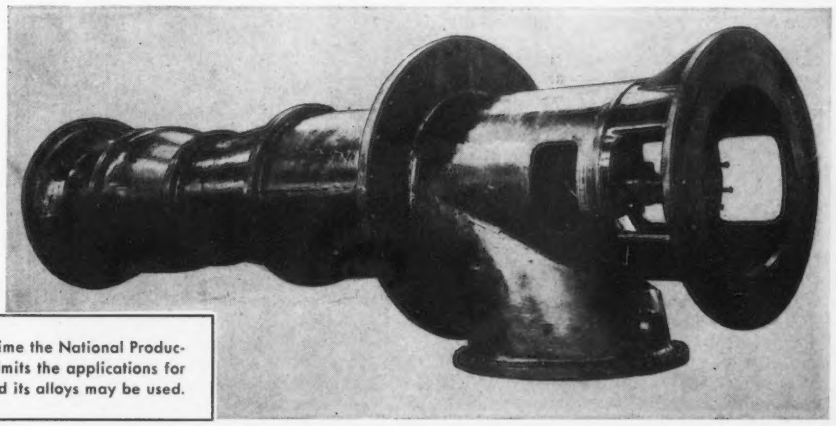


↑ **Light Castings . . .** These piston rings are produced in Ni-Resist for engines used in corrosive service.



↑ **Medium Castings . . .** Free from tendencies to corrode, comminutor parts cast in Ni-Resist lengthen life of sewage disposal equipment.

**Heavy Castings . . .** Casing, outer column and discharge head of this 14-ton pump are cast in Ni-Resist for resistance to salt water and other corrosive media. ↓



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provided the rivets are properly cadmium plated.

The fatigue life of structures will not be seriously impaired, by the use of stainless steel rivets.

The rivet material used in these investigations was Type 304 stainless steel.—PDA.

3.7.3, 6.2.5

**Effect of Cold Work at Low Temperature on Austenitic 18-8.** W. O. Binder. Union Carbide and Carbon Res. Lab., Inc. *Metal Progress,* **58,** No. 2, 201-207 (1950) Aug.

The effect of low-temperature straining on the strength of austenitic 18-8 chromium-nickel steel was investigated after an 18-8 valve stem, following 15 years of use in equipment making oxygen, had transformed partially to martensite. Fundamentally, cold work causes the metastable austenitic phase to transform partially to the stable ferrite phase. This transformation affects the mechanical and physical properties of the steel considerably, both at elevated and at low temperatures, increasing the strength hardness and magnetic permeability of the steels and lowering their ductility and shock resistance. The extent to which the transformation proceeds depends, however, on the composition of the steel, temperature of cold work and the rate of deformation. The present investigation was performed on 304 and 347 steels in the form of heavy plate and after welding. This material is very extensively used for fabricating low-temperature equipment. The results of the tests are summarized in graphs and tables and show that overstraining at subzero temperatures lowers the subzero toughness of 304, 347, and austenitic 18-8 steels. However, strains in excess of yield-strength loading are required to induce measurable amounts of transformation. Transformation due to 2 percent straining at low temperature has only a minor effect on the subzero strength of the subject steels.—TDD.

3.7.3, 3.7.2, 6.4.2

**Corrosion Rate and Etch Structures on Aluminium: Effect of Heat-Treatment and Impurities.** B. Roald and M. A. Streicher. *J. Electrochem. Soc.,* **97,** No. 9, 283-289 (1950).

The effect of heat-treatment of specimens of aluminum ranging in purity from 99.2 to 99.998 percent on the rates of dissolution and resulting etch structures in hydrochloric acid and sodium-hydroxide solutions is described. The specimens were process-annealed at 360° C and some were then heated at 575° C, from which temperature half were allowed to furnace-cool whilst half were quenched in water. It is shown that: 1) with 99.99, 99.88, and 99.57 percent material, larger grain-size resulted when the specimens were quenched than when they were air-cooled. 2) Increasing the impurity content of the aluminum from 0.002 to 0.8 percent resulted in only an 8-fold increase in the rate of attack by the sodium hydroxide but in a 30,000-fold increase with hydrochloric acid. 3) Heat-treatments had no effect on the rate of dissolution in sodium hydroxide. 4) Heat-treatments were most effective in reducing the rate of attack of hydrochloric acid over a narrow range of impurity content, indicating that a change in solid solubility was involved. 5) Intergranular attack on aluminum appears to be determined by: a) composition of metal, i.e. type and quantity of impurities, b) the heat-treatment cycle to which the metal was subjected; c) the type of corroding solution; in some cases hydrochloric acid but not sodium hydroxide produces intergranular attack and sometimes vice versa; d) the orientation of the grains in relation to each other. 6) When specimens of aluminum of 99.99, 99.97, 99.88, and 99.57 percent purity were dissolved in hydrochloric acid, a fine dust remained which consisted of rectangular blocks 0.005 mm long, similar in structure to those observed on the surface of the metal. Highest purity (99.998 percent) aluminum did not give this effect.—MA.

3.7.3, 3.2.2

**Effect of Cooling Rate and Composition on the Embrittlement of Weld Metal.** E. C. Rollason and R. R. Roberts. *J. Iron Steel Inst.,* **166,** 105-112 (1950) Oct.

Tensile specimens of extremely rapidly cooled (e.g. 1400° C per min.) mild-steel weld metal have low ductility associated with woody fractures. In welds with high hydrogen content, microfissures similar to hair-line cracks were also found, and these prevent complete recovery of ductility by tempering at 650° C. Extent of fissuring was shown to be related to hydrogen and nitrogen contents of the weld. Suggests that fissuring is caused by the embrittling effect of hydrogen on regions of the weld already reduced in ductility by the presence of carbon- and nitrogen-rich intermediate transformation products of austenite. A study was made of effects of fissuring and nitrogen solubility of alloy additions to weld metal.—BLR.

## 3.8 Miscellaneous

3.8.3, 3.6.5, 3.5.9, 6.2.5, 6.3.6

**Fundamental Corrosion Research.** M. G. Fontana. Ohio State University. Summary Technical Report on Office of Naval Research Contract N6 ori-17, T.O. II, 85 pp. May, 1949.

The report covers research on the mechanism of corrosion and the passivation of various steels, the influence of flowing solutions on the electric potentials of copper and its alloys in ionic concentration cells with and without oxygen, and the oxidation mechanism of stainless steel.

3.8.3, 6.2.5

**Passivation of Stainless Steels in Certain Strong Acids.** (In French.) J. M. Defranoux. *Compt. Rend.,* **231,** 901-903 (1950) Oct. 30.

The above was investigated for steels using dilute sulfuric acid plus 1-2 percent nitric acid. Influence of surface condition on passivation as a function of temperature and time was emphasized.—BLR.

3.8.4

**Phenomena of Internal Oxidation.** (In French.) J. Druyvesteyn. *Metaux & Corrosion,* **25,** 277-282 (1950) Nov.

Deals especially with the better-known and simpler types of the above, theory of which is well developed. Diffusion of oxygen in silver or copper alloys; mechanical properties of silver or copper alloys; microscopic investigation of precipitation in the same alloys; application of thermodynamics to internal oxidation of various nonferrous metals; and lattice dimensions of vacuum-cast silver and several silver alloys are discussed. Tables, micrographs and macrographs.—BLR.

3.8.4

**Theory and Corrosion. Cathodic Behaviour of Platinum, Palladium and Lead in Acid Bichromate Solution.** C. A. Knorr. Abstract of paper to Ver. deutsch. Chem., 1950. *Werkstoffe u. Korrosion,* **1,** 508-509 (1950) Dec.—INCO.

# 4. CORROSIVE ENVIRONMENTS

## 4.3 Chemicals, Inorganic

4.3.2, 6.5

**Corrosion. Hydrochloric Acid Versus Materials of Construction.** M. G. Fontana. *Ind. & Eng. Chem.,* **42,** No. 8, 69A-70A, No. 9, 111A-112A (1950) Sept.

For use with hydrochloric acid author classifies alloys into those: 1) generally used and suitable for applications; 2) used with caution and under special conditions; and 3) generally unsuitable. In the first paper (August) author deals with classes 2) and 3) from the point of view of digiculties due to corrosion, particularly from impure HCl, and behavior of many metals and alloys under various conditions. The second article (September) deals with materials, class 1 (i.e., Chlorimet 2 and 3; Durichlor; Hastelloy A, B and C; and tantalum.)

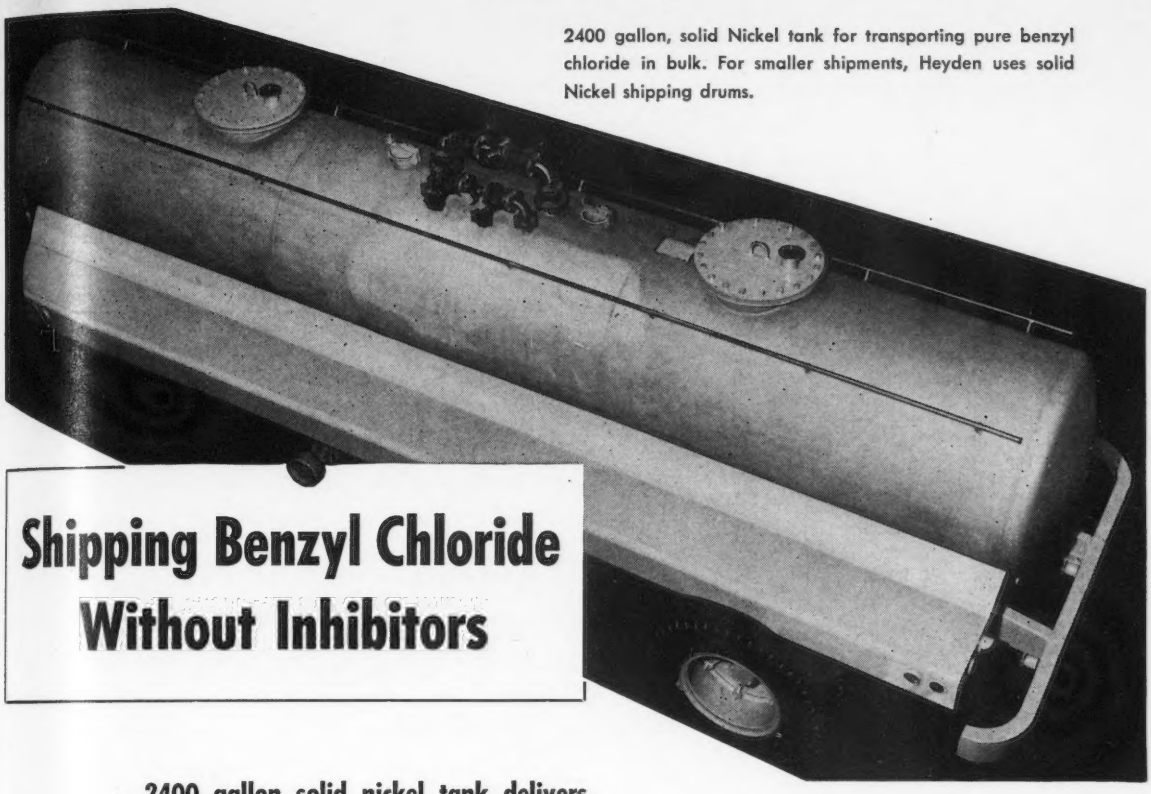
4.3.2, 6.2.3

**The Effect of Acid Concentration on the Rate of Corrosion of Carbon Steels.** S. A. Balezin and T. I. Krasovitskaya. *J. Applied Chem.* (USSR), No. 2, 197-202 (1951).

It is well known that the rate of solution of steel in sulfuric acid increases with the acid concentration up to a certain value and then falls off sharply. The maximum corrosion effect corresponds to 11 to 14 N acid. All of the steels tested became passive in an acid having a normality in excess of 17. The curve "rate of solution vs. concentration of nitric acid" exhibits a maximum analogous to the curve obtained with sulfuric acid. The rate of corrosion of carbon steels in hydrochloric acid increases continuously with increasing concentration of the acid, however, the rate of increase is not constant. In the initial range of concentrations (0.5 to 4 N) the rate of corrosion increases slowly, while at higher concentrations (4 to 7 N) quite rapidly.

However, the problem important from the practical point of view, of quantitative relationships between acid concentration and rate of corrosion has been investigated only with respect to sulfuric acid and the data are not in agreement.

The present work verifies Novikov's equation. Eight grades of carbon steel were tested in various concentrations of pure sulfuric, hydrochloric and acetic acids. It was established that the activity of above acids "a" is related to their corrosiveness with respect to the carbon steels, over a broad range of concentrations, by the general equation: P



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$= k\ a^n$, where K and "n" are constants. Constant of "n" characterizes the nature of the acid. For sulfuric acid n 0.67, for hydrochloric acid n 0.85 and for acetic acid n 0.33.

Complete translation available from Associated Technical Services, P. O. Box 271, East Orange, N. J.

**4.3.3, 3.5.9**

**Oil Ash Corrosion of Materials at Elevated Temperatures.** C. T. EVANS, JR. ASTM Reprint. Special Technical Publication No. 108, 1950, 47 pp.

Ash from residual fuel oils can be highly corrosive to materials at elevated temperatures, particularly when it contains substantial quantities of vanadium. This paper presents results of extensive tests on a wide range of heat- and creep-resisting materials, ferrous and nonferrous, in ashes derived from heavy fuel oils from different sources. Possible use of protective coatings and of methods of reducing vanadium content of oils considered.—BNF.

**4.3.3, 3.5.9**

**High-Temperature Corrosion When Burning Some Oils.** E. N. SKINNER AND R. A. KOZLIK. Paper, Petr. Mech. Eng. Conf., New Orleans, Aug. 25-28, 1950. Abstr. *Combustion*, **22**, No. 5, 69 (1950) Nov.

Investigations on high-temperature corrosion of superheater spaces when burning some types of heavy fuel oil containing vanadium compounds have led to the following conclusions: 1) Vanadium content and the co-presence of alkali in the oil are primary factors with temperature, metal composition and time of exposure as supplementary factors. 2) At metal temperatures not above 1200° F corrosion probably proceeds at a negligible rate due to the absence of molten constituents in the ash. 3) Pure vanadium pentoxide alone is a potent oxidation accelerant when in contact with certain alloys, particularly those containing significant amounts of molybdenum. 4) Vanadium pentoxide in combination with sodium sulfate accelerates scaling by promoting extensive sulfidation of the underlying metal.

**4.3.3, 3.4.6, 3.5.9**

**Rapid Oxidation of Metals and Alloys in the Presence of $MoO_3$.** G. W. RATHENAU AND J. L. MEIJERING. *Metallurgia*, **42**, 167-172 (1950) Sept.

Describes experiments in which copper and heat-resisting copper alloys, iron and heat-resisting iron alloys, nickel and nickel-chromium alloys and silver and silver-aluminum were oxidized at elevated temperatures in the presence of molybdenum trioxide and air. Molybdenum trioxide promotes oxidation by formation of liquid-oxide phases in which atoms of the basic metal can take part. Owing to incorporation of molybdenum into the scale, oxidation resistance may be affected below the lowest eutectic. In the case of silver alloys, molybdenum trioxide plays an additional role, since oxidation of silver above 180° C is possible only by complex-oxide formation. The results are discussed in detail. Includes photomicrographs.—BLR.

**4.3.3, 7.6.4, 4.4.6**

**Vanadium in Crude Oils.** W. L. NELSON. *Oil Gas J.*, **49**, No. 30, 88; No. 31, 105-106; No. 33, 330; No. 34, 83 (1950) Nov. 30, Dec. 7, Dec. 21; **50**, No. 35, 65 (1951) Jan. 4.

Questions on the effect of vanadium content on combustion, corrosion, deposition of the residue when used in boilers and furnaces, steel work and refractories and on high nickel or 18-8 furnace tubes operating at 1400° F. The occurrence, ash analysis, effect of ash and vanadium penta-oxide on refractories, and the effect on steels and alloys are discussed. Spacers of 28 chromium 12 nickel alloy are used in boilers to keep superheated tubes in position. They are subjected to a temperature of 1800° F and are not cooled. Vanadium appears to fuse with the spacer material destroying it in a short time. There is some speculation that vanadium may extract chromium and nickel from the alloys. When subjected to 1650° F or higher, vanadium, molybdenum or wolfram oxides hasten the rate of corrosion of steels or alloys containing them. 410 stainless steel was little affected by vanadium oxide, plain carbon steel was affected somewhat, but a 7.89 chromium, 2.06 vanadium steel was vigorously attacked at 1650° F in 19-29 hours. For samples exposed to molten vanadium oxide at 1320° F, at the liquid line, corrosion proceeded so rapidly that a notch was produced after a few hours of exposure.—INCO.

**4.3.6, 6.3.11**

**The Rate of Corrosion of Silver in Solutions of Ferric Sulfate.** H. SALZBERG AND C. V. KING. New York Univ. Paper before Electrochem. Soc., Buffalo Meeting, Oct. 11-13, 1950. *J. Electrochem Soc.*, **97**, No. 9, 290-297 (1950) Sept.

Metals down to copper in the emf series dissolve in ferric salt solutions at maximum, diffusion controlled rates, with quantitative reduction of ferric to ferrous ion, but silver reaches an equilibrium with only partial reduction of ferric ion, and the dissolution rate is smaller than with more active metals. The corrosion or dissolution rate of silver in ferric salt solutions was studied as a function of: a) the concentration of the ions involved, b) the concentration of the acid, c) speed of stirring, d) temperature, and e) emf of the silver-silver ion, ferric-ferrous ion cell. The rate was found to be greatly influenced by adsorption of ions formed in the reaction. A rate equation was derived which includes the effects of adsorption and of the reverse reaction.—INCO.

## 4.4 Chemicals, Organic

**4.4.8, 8.4.2, 3.4.6, 3.4.8**

**Corrosion Problems in Gas-Purification Units Employing MEA (Monoethanolamine) Solutions.** F. C. RIESENFELD AND C. L. BLOHM. *Petroleum Refiner*, **24**, No. 4, 141-150 (1950).

Experiments are described in which the corrosion of a number of ferrous metals, of commercially pure aluminum, and aluminum-1.2 percent manganese alloy was investigated under the following conditions: 1) in amine solutions in the presence of carbon dioxide, 2) in amine solutions in the presence of carbon dioxide and hydrogen sulfide, and 3) in a glycol-amine-water solution in the presence of carbon dioxide and hydrogen sulfide in a dynamic system. The behavior of aluminum-iron galvanic couples was also studied. Aluminum was appreciably attacked by amine-water mixtures, in the absence of carbon dioxide, particularly at high temperatures. The presence of glycol, especially above 40 percent, inhibited the attack to a marked extent. Carbon dioxide also reduced attack, e.g. a solution containing monoethanolamine 15, water 85 percent and 0.08 per mol. of amine, showed very little attack. There was no attack on aluminum under the conditions described at 2). In glycol-amine-water solutions in the presence of carbon dioxide and hydrogen sulfide steel corrodes and aluminum is unattacked in a galvanic couple of the two metals, but in aqueous amine solutions in the absence of glycol but in the presence of carbon dioxide and hydrogen sulfide, neither metal showed appreciable corrosion. In the absence of the two gases, the aqueous amine solutions cause considerable corrosion of the aluminum member of the couple, but when glycol was present in addition, no attack occurs on either metal. Under the conditions described at 3) no attack took place on the aluminum. Full experimental details are included in the paper.—MA.

## 4.5 Soil

**4.5.1, 7.2**

**Corrosion and Its Control—What the Soil Does to Pipe.** M. E. PARKER. *Oil Gas J.*, **49**, No. 40, 111 (1951) Feb. 8.

**4.5.1, 3.6.3**

**The Thermal Conductivity of Soils.** ANDREW GEMANT. *J. Applied Phys.*, **21**, 750-752 (1950) Aug.

Calculates the above of varying moisture content (5-25 percent) on a physical basis. Results agree with experimental data in the literature. Influence of soil composition on conductivity is also explained by theory.—BLR.

## 4.6 Water and Steam

**4.6.1, 5.4.5, 5.3.2**

**Protection from Rusting of Steel in Under-Water Structures.** K. MULLER. *Bautechnik*, **27**, 296-298 (1950); *Chem. Abs.*, **44**, No. 22, 11119g (1950).

A discussion of chemical and mechanical effects of fresh and sea water and means of protection from them by paints, solutions of tar, pitch, or hot bitumens and metallic coats.—RPI.

**4.6.2, 6.3.10, 7.2**

**Alloy Steel Valve Casting Unimpaired After 6 Years' Service.** *Steel*, **127**, 66 (1950) Dec. 25. From paper by T. N. ARMSTRONG AND R. J. GREENE.

Results of study indicate no loss of strength, no embrittlement, and no occurrence of graphite in the welded valve casting of nickel-chromium-molybdenum steel, of approximately WC-4 grade, after exposure to steam at 900° F for a period of 6 years.—BNF.

**4.6.2**

**A System of Water Treatment for Boilers up to 900 Psi—With Low Make-up.** CHARLES L. WOLFF, Plant Engineer and IRVING LEIBSON, Student Engineer, Florida Power and Light Co., Mi-

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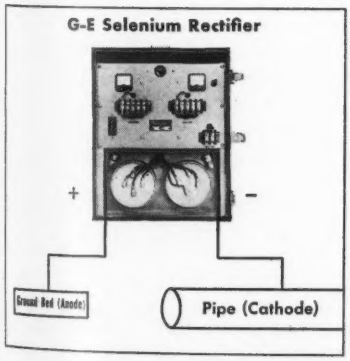
# Prevent Costly Pipeline Corrosion

Pipelines—and other underground metal surfaces—are constantly subject to destructive galvanic corrosion.

This condition occurs under all uncontrolled circumstances, depending upon soil conductivity, moisture content, dissolved oxygen content, temperatures, protective coatings, dissimilar metals, position of other metallic structures, stray currents, etc. The way to prevent this costly damage to your underground equipment, is to counteract harmful galvanic action. G-E Cathodic Protection Rectifiers, as part of a properly installed system, will do just that.




**HOW IT WORKS**

Engineers know corrosion occurs when one metal acts as a cathode, and another as an anode in an electrolyte, such as soil or water. The metal which acts as the anode slowly corrodes, pits, and eventually disintegrates.

The G-E Cathodic Protection Rectifier makes your pipeline the **cathode,** thereby eliminating galvanic actions, as shown in the sketch above.

**FAST INSTALLATION**

The G-E Cathodic Protection Rectifier is shipped completely assembled. A bracket on the unit permits mounting directly on a pole or wall, and specially constructed foundations are not required. Connectors are designed for rapid installation.

**LOW MAINTENANCE**

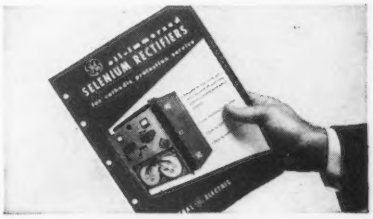
There are no moving parts to wear out in the G-E Cathodic Protection Rectifier. Hermetically sealed, oil-immersed selenium rectifier stacks are long-lived. Oil cannot oxidize or absorb moisture, and never has to be replaced. Access door facilitates meter reading, and inspection of the unit. Two spring clasps retain door, and a hasp is provided for padlocking.

**WITHSTANDS SEVERE WEATHER**

General Electric's double-walled construction has been developed to withstand extreme variations in weather conditions, most common where cathodic protection is most essential.

**INFORMATION AVAILABLE**

Because conditions differ in practically every installation, each cathodic protection system should be individually engineered to assure complete protection. For further information on the G-E Cathodic Protection Rectifier or on cathodic protection systems, write today for literature.

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ami. *Southern Power and Ind.*, **68**, Nos. 8, 9; 64, 72 (1950) Aug., Sept.

Part 1 of this 3-article series discusses methods of pretreating evaporator feedwater, and evaporator operation as related to the water conditioning program.

In Part 2, the authors suggest maintaining feedwater pH of 8.5-8.8 by recirculating boiler blowdown water and continuous feed of sodium sulfite to prevent feed system corrosion. Suggested values for boiler water sulfite, silica, total solids and pH-phosphate relationship are given.

4.6.4, 5.8.2

**Cooling Systems—Coolant—Inhibitors.** H. G. SMITH. *Diesel Progress*, **16**, No. 10, 58, 64 (1950) Oct.

Discussion includes source of water, rate of rust formation and corrosion, contamination of coolant and effect of rust deposits. Procedure to follow is to be sure the water is clean and then use an inhibitor. Treatment of water for rust prevention in the cooling system after antifreeze has been used is given. —INCO.

4.6.4

**Controlling Scale in Cooling Tower Waters Without Increasing Water Use.** M. A. ENQUIST. *Oil Gas J.*, **49**, No. 45, 88+ (1951) Mar. 15.

Scale formation in cooling towers is controlled by passing the water through a bed of a mineral known commercially as Scalite, which is incorporated into the cooling system. The bed acts as a filter and also has an effect similar to the seeding of supersaturated solutions. A high-molecular weight organic additive known as Anti-Mist is added to prevent water from misting and drying on the poorly wetted portions of the evaporation screen. The amount of water circulated through the bed averages 1-2 percent of the tower circulation rate. The pH is automatically controlled, leading to inhibition of corrosion. When the method was applied to a brine-cooling system periodically contaminated with sulfuric acid, the corrosion rate was reduced from 100 to less than 10 mg. per sq. dm. per day.

4.6.6, 2.3.5, 5.8.2

**Corrosion Due to Tuberculation in Water Systems. I. The Effect of Calgon on the Potential of Iron Electrodes in Differential Aeration Cells With Running Tap Water. II. The Effect of Calgon on the Potential of Zinc and Copper Electrodes in Differential Aeration Cells With Running Tap Water.** (In English.) J. L. MANSA AND WACLAW SZYBALSKI. *Acta Chemica Scandinavica*, **4**, No. 8, 1275-1299 (1950).

Experimental apparatus is described and diagrammed; results are charted and discussed. 38 references.—BLR.

4.6.6, 2.3.5, 5.8.2

**Corrosion of Steel in Laminar Flowing Water.** J. L. MANSA. *Acta Chimica Scandinavica*, **4**, 1263-1274 (1950).

Investigation of the formation of the rust layer upon an iron surface overflown by water, in studying tap water corrosion in galvanized and non-galvanized iron pipe. The description and preparation of the test cell, the development of rust during a normal test and on polished cast iron, at smaller and larger velocities, on disks with a galvanized zone and with water containing Calgon, the microscopical development, quantitative measurements, and the electrochemical explanation are discussed. The test disk was cut from 0.10-0.40 carbon rolled steel. Illustrations, a table of water analysis and 3 references are given.—INCO.

## 4.7 Molten Metals

4.7, 2.3.4

**Progress Report No. 2; September 16-December 15, 1950; Problem No. 539.** J. L. EVERHART AND E. L. VAN NUIS. American Smelting and Refining Co. Jan. 2, 1951. 8 p.

In static tests, samples of various construction materials are exposed to attack by liquid low-melting alloys for 500 hr. at 1200° F. Tests have been run, during the period, on four samples of Ti-base alloys in contact with bismuth-lead, bismuth-lead-tin, bismuth-lead-indium, and bismuth-indium-lead-tin alloys. Tests were run also on commercial titanium and stainless steel Type 316 in contact with bismuth-indium-lead-tin. Two titanium alloys, one containing 4 percent chromium and the other 4 percent chromium and 3 percent aluminum, have resisted attack under these conditions as well as the high chromium stainless steels, which were the best of the materials tested previously. In dynamic tests, samples of construction materials have been exposed to attack by various liquid low-melting alloys for 1000 hr. under dynamic conditions (slow-circulation) in a series of corrosion harps. Two samples are included in each run, one polished, the other with the surface "as received" from the supplier. Type 446 steel submerged in bismuth-lead showed little attack, the results being similar to those obtained previously under static conditions. The "as received" samples were attacked at slightly greater rates than the polished samples. However, samples exposed to attack by the bismuth-indium-lead alloy were attacked at a greater rate under dynamic than under static conditions, with the polished sample showing a higher rate of attack than the "as received" sample. The 4 percent chromium-titanium alloy tested in bismuth-lead at 900° F showed mild attack. A capillary viscometer has been constructed of Pyrex glass to determine the viscosities of a number of the low-melting alloys which were developed during the early stages of this investigation. A Jacobs viscometer is described based on the principle of measuring the torque exerted on a rotating body which is immersed in a liquid.—BLR.

4.7, 6.3.21

**Gallium — A Byproduct Metal.** A. P. THOMPSON AND H. R. HARNER. The Eagle-Picher Research Labs. *J. Metals*, **191**, No. 2, 91-94 (1951) Feb.

Gallium has most unusual properties, melting at 29.75° C (85.5° F) and boiling at 1983° C (3601° F), thus exhibiting one of the longest liquid ranges of any element; as will be observed, the melting point is below body temperature. In a recent release by the Atomic Energy Commission, the properties of gallium are discussed quite thoroughly: Gallium is more aggressive in its attack on most solid metals at a given temperature than is any other molten metal that has been tested. It can be contained successfully at high temperatures only in some refractory oxides, quartz, graphite, and such metals as wolfram and tantalum. A wide variety of uses have been suggested for gallium, ranging from low-melting-point alloys to the treatment of bone cancer. It has useful application in organic synthesis, as a possible heat-exchanging medium to be used for extracting heat from a high level and, because of its low melting point, for use in fire-alarm system. Gallium increases the hardness of aluminum ternary alloys, and on heat treating will harden magnesium. Gallium may also find a place in electrical contact alloys.—TDD.

4.7, 6.2.2

**Does Nodular Iron Resist Zinc?** J. E. REHDER. *Am. Foundryman*, 17, No. 62 (1950) Jan.

An inquirer asks about the suitability of nodular iron kettles for melting zinc and its alloys. The Canadian Bureau of Mines are carrying out tests on a commercial scale, but full results are not yet available. The writer suggests that a nodular iron mould should last several times as long as grey iron. A nodular iron plunger in a zinc alloy die casting machine has given good service.—ZDA.

4.7, 6.2.3

**The Corrosion of Steels in Molten Zinc.** DICKENS AND BRAUNS. Board of Trade, Tech. Inf. Documents Unit, German Div. FD 485/50.

A report on an investigation carried out in Germany during the war into the attack of molten zinc on steels. The investigators found that in wet galvanizing baths free from aluminum, silicon-free low carbon steels exhibited lowest solubility; whereas, in dry galvanizing baths in which the zinc contained aluminum, higher silicon steels gave the best results. A specimen of specially heat-treated steel containing 1.2 percent carbon and 1 percent chromium was hardly attacked at all in a dry bath, but in the wet bath, it was completely dissolved in a short time.—ZDA.

# 5. PREVENTIVE MEASURES

## 5.2 Cathodic Protection

5.2.1

**Install Protection on Existing Lines.** M. C. MILLER. *Gas*, **26**, No. 12, 72 (1950) Dec.

5.2.1, 8.4.3

**Cathodic Protection of Condensers and Heat Exchangers.** M. E. PARKER. *Oil Gas J.*, **49**, No. 50, 244 (1951) Apr. 19.

5.2.1

**Attentuation Curves in Cathodic Protection.** *Oil Gas J.*, **49**, No. 45, 85 (1951) Mar. 15.

5.2.1, 5.4.7, 7.2

**Corrosion Study.** P. REED. *Oil Gas J.*, **49**, No. 43, 26-27 (1951) Mar. 1.

Basic principles and techniques of instruments, coatings and cathodic protection for pipelines were presented at the Second Annual Tulsa Short Course for Pipeliners, (2/21-3/51), by members of

the Nat'l. Assn. of Corrosion Engineers. The rapid increase in the use of galvanic anodes, especially of the magnesium type, has resulted in substantial savings. An important trend in coating practice has been the increased use of new types of intermediate coatings suitable over a wide temperature range. Differential aeration was stressed as perhaps the major cause of pipe-line corrosion.

5.2.1, 1.2.2
**Planning a Corrosion Control Program: V. Cathodic Protection of New Lines and Systems.** H. S. RIDDLE. *Gas*, **26**, No. 12, 71 (1950) Dec.

Total cost of cathodic protection installed on a new, well-coated pipe line system was about 1 percent of the total cost of the system. An average saving of 20 percent in weight of pipe used is being realized with cathodic protection.

5.2.1, 1.3, 8.9.5
**The Cathodic Protection of Ships' Hulls in Sea Water, A Critical Review of the Problem.** S. SCHULDINER. U. S. Naval Res. Lab. (PB 101169) 65p Jan. 1950.

A review of the general theory of corrosion and cathodic protection is presented together with a survey of the work done on the specific problem of the cathodic protection of ships' hulls in sea water. The literature is analyzed and various suggestions made for the conduct of further research.

5.2.1, 1.2.2
**Cathodic-Protection Costs.** R. B. WILSON. Paper, 32nd Ann. A.G.A. Conv., Atlantic City, Oct. 1950. Abstr. *Oil Gas J.*, **49**, No. 22, 127-128 (1950) Oct. 5.

The average annual unit total cost is approximately $21 per mile of 3-inch equivalent main under protection.

5.2.1
**Basic Principes of Cathodic Protection.** M. E. PARKER. *Oil Gas J.*, **49**, No. 42, 194+ (1951) Feb. 22.

Diagrams illustrating cathodic protection of a pipe line, an offshore drilling platform, of the interior wetted surface of an elevated water tank and a domestic water heater are given.—INCO.

5.2.1, 1.2.2
**Management's Attitude Toward a Corrosion Control Program.** R. B. WILSON. Miss. Power & Light Co. Paper, A.G.A. Atlantic City, Oct. 1950. *Gas Age*, **100**, No. 10, 38-40+ (1950) Nov.

The successful application by the author's company of cathodic protection to its distributing mains is described. Costs have been reduced to approximately 1 percent of the pipeline construction cost.

5.2.2, 8.8.1
**Combating Corrosion in a Chemical Plant with Magnesium Anodes.** O. OSBORN. *Corrosion*, **7**, No. 1, 2-9 (1951) Jan.

Cathodic protection of steel and cast iron in a chemical plant is economically justified and feasible from an engineering point of view under certain conditions. Magnesium anodes are useful under conditions which are restrictive as to space and accessibility. Principal use of magnesium anodes for cathodic protection of portions of the Dow Chemical Company's Freeport, Texas, plant were in structures handling large volumes of sea water and brine both static and in motion. Studies indicate that the cost of the remedial measures is much


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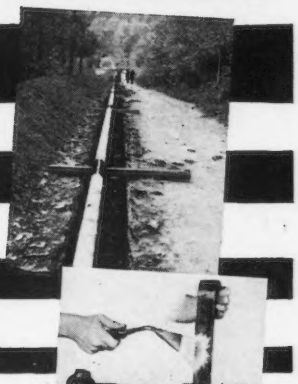

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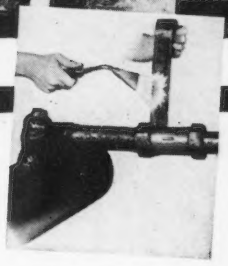

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less than would be the cost of replacing structures corroded to destruction, even when considerations of uninterrupted service, loss of production from down time and other factors are disregarded. Experimental installations are being studied and new aspects of the possibilities are constantly being investigated.—EL.

**5.2.2, 8.9.5**

**Cathodic Protection of an Active Ship in Sea Water. Part II.** K. N. BARNARD, Naval Research Establishment. *Corrosion*, **7**, No. 4, 114-117 (1951) Apr.

HMCS "New Liskeard" was drydocked 12 May '50, eleven months after magnesium anodes were fitted to each bilge keel. No corrosion was observed on the underwater hull except in a few reentrant places. The general condition of the underwater paint was fair and the ship was relatively free from fouling growth. The current required for protection varied between 20 and 35 amp, depending on the conditions under which the ship operated. The consumption of magnesium was 435 lb. for the 11-month period. The results show that it is possible and practical to use magnesium anodes to protect cathodically an active ship in sea water and that the measurement of the "hull potential" is an effective criterion as to how much current should be applied at a given time. The possibility of lengthening the period between drydockings of active ships from one year to two years is indicated.—TDD.

**5.2.2, 8.9.5, 4.6.11**

**Cathodic Protection of an Active Ship in Sea Water.** K. N. BERNARD AND G. L. CHRISTIE. Naval Research Establishment, Halifax, Canada. *Corrosion*, **6**, No. 7, 232-234 (1950) July.

A mine sweeper, having a length of 225 ft., a beam of 35.5 ft., and an underwater surface area of 7500 sq. ft., was fitted with a cathodic protection system that has apparently been practical and adequate.

The system consisted of ten magnesium alloy anodes, weighing about 80 lb. each, secured to the bilge keels and insulated from the steel hull of the ship. The five anodes of each side were connected in parallel and a single lead from each group was taken to a variable resistance and an ammeter before it was connected to the frame of the ship. Hull potentials were measured with respect to a silver—silver chloride electrode in sea water.

Observations were made at a jetty berth, on speed trials, and on several cruises. Potentials at the jetty and underway ranged from 800 to 872 mv over a 3-month period, demonstrating that the ship was protected. With the ship underway and with the hull potential between 320 and 840 mv, the mean current output was 31.9 amp. With the ship stationary, the current for this range was 29.4 amp. There was a slight depolarization when the ship got underway, but this became less severe as the polarization film aged.

The cost was calculated as five cents per square foot per year or four-hundred dollars for this ship, exclusive of the cost of installation. The total expenditure would result in a saving in maintenance costs over the life of the ship. The expense would be less if the anodes could be suspended at a little distance from the steel being protected. —PDA.

**5.2.2**

**Performance of Magnesium Anodes Under Actual Service Conditions.** T. H. GILVERT. *Gas Age*, **106**, 40-41 (1950) Nov. 23.

Current output of Galvo-Pak magnesium anodes is plotted as a function of anode size and soil resistivity.—BLR.

**5.2.2**

**For Anodic Protection.** *Modern Metals*, **6**, No. 12, 44 (1951) Jan.

The Apex Anode-Pak made by Apex Smelting Co., Chicago, Ill. contains a 17 or 32 pound magnesium anode with a chemically balanced backfill in a permeable cloth sack. A ten-foot insulated copper wire is attached and the entire assembly is packed in a shipping container ready for installation. The backfill is carefully prepared to provide the longest possible life at lowest cost. Bare metal anodes are also supplied in 17, 32, and 51 pound sizes, with or without wires.—ALL.

**5.2.3**

**Design of Anode Systems for Cathodic Protection of Underground and Water Submerged Metallic Structures.** E. R. SHEPARD AND HENRY J. GRAESER, JR. *Corrosion*, **6**, 360-375; discussion, p. 375 (1950) Nov.

Presents results of an extensive study of factors involved in the above. Numerous graphs, tables, and diagrams.—BLR.

**5.2.4**

**Criteria for Cathodic Protection.** *World Oil*, **131**, No. 1, 177-178 (1950) July.

Discusses economic considerations in installation design, magnesium anodes, etc.—BNF.

## 5.3 Metallic Coatings

**5.3.2, 2.2.2, 2.3.2**

**The Effect of Copper Undercoats on the Protective Value of Nickel-Chromium Coatings on Steel.** B. B. KNAPP AND W. A. WESLEY. INCO Bayonne TP No. 174, Jan. 26, 1950, 33 pp (Ms in Tech Files) *Plating*, **38**, No. 1, 36-38+ (1951) Jan.

Corrosion tests were performed on a limited number of panels of high-carbon steel plated with nickel-chromium and with copper-nickel-chromium coatings. These tests showed that composite coatings containing a considerable proportion of copper were decidedly inferior to copper-free coatings of equal thickness in a normal and a salt-accelerated industrial atmospheric exposure and in a salt-spray test. It was shown, by exposure tests in which the wash from copper and iron screens was permitted to drip onto plated panels, that both copper and iron corrosion products themselves can accelerate corrosion of nickel-chromium coatings. It is postulated that the corrosiveness of copper corrosion products accounts in part for the poor protective value of a copper layer. A thin coating of copper under the nickel exhibited a beneficial effect in the early stages of the atmospheric tests, but this advantage was soon vitiated by the adverse effect of the copper corrosion products. Many graphs and tables.—INCO.

**5.3.2, 1.3**

**The Resistance of Nickel and Chromium Plating to Corrosion.** J. LIGER. *Galvano*, **19**, No. 166, 15-19 (1950).

The first instalment of an elementary review.—EL.

**5.3.2, 1.3**

**Precious Metal Plated Finishes for Die Castings. Part Two.** *Die Castings*, **8**, 39-41+ (1950) Dec.

Reviews recent literature on silver plating of die castings. Bath compositions are tabulated; other data are charted.—BLR.

**5.3.2**

**Zinc Plating for Corrosion Resistance and Decorative Purposes.** S. R. GOODWIN. *Electroplating*, **3**, No. 14, 524-528 (1950) Oct.

A review of zinc plating processes, with details of surface preparation, solution compositions and operating conditions. Sulfate and cyanide baths are discussed, and particular attention is paid to bright zinc solutions. The valuable corrosion resistance of zinc plate is emphasized, and it is stated that a deposit formed by a new bright process (Promat) is hardly to be distinguished from chromium. Results are quoted for its behavior in the K.110 and intermittent salt spray tests.—ZDA.

**5.3.2, 5.3.4, 6.4.2**

**Effect of Bath Composition on Aluminum Coatings on Steel.** D. O. GITTINGS, D. H. ROWLAND, AND J. O. MACK. Am. Soc. Metals, Preprint No. 3, 1950.

Antimony, beryllium, bismuth, cadmium, calcium, chromium, cobalt, copper, germanium, lead, magnesium, manganese, nickel, silicon, silver, tin, titanium, vanadium and zinc were added individually in various amounts to experimental hot-dip aluminum-coating baths for rimming and low-carbon steels. Their effects on layer thickness, microhardness, flat-bend-test performance, and appearance were studied. Results are presented in tables, graphs and micrographs and are discussed.—BLR.

**5.3.2**

**The Corrosion Resistance of Galvanized Coatings.** E. F. PELLOWE. Internat. Hot Dip Galvanizing Conf. Preprint, July, 1950. 12 pp.

The sequence of operations in a modern plant galvanizing windowframes is described. The main part of the paper deals with the effect of mechanical damage on coating life and reviews published work on the resistance of galvanized coatings to atmospheric corrosion at sites throughout the world. The author discusses behavior of galvanized coatings in diverse applications. —BNF.

**5.3.2**

**Non-Electrolytic Nickel Plating as a Protective Coating During Nitriding.** (In Czech.) JAN KORECHY. *Hutnicke Listy*, **5**, 414-416 (1950) Oct.

Above process developed by A. Brenner of the National Bureau of Standards (U. S.) was found to be suitable for local protection during nitriding. A layer 0.002-0.003 mm thick, grown in 10-15 minutes is said to be adequate for protection during the usual nitriding process. (500°C. for 48-96 hours).—BLR.

**5.3.2, 5.3.4**

**Galvanizing (Hot-Dip).** HEINZ BAB-

LIK. Third edition. Translated from the German by Clive A. Bentley. Pp. xiv+502, 1950. London: E. & F. N. Spon Ltd., 22 Henrietta Street, W.C.2. (70s. net.)

The first chapter deals with the formation of scale and is followed by concise dissertations on pickling theory and practice. The theoretical side of pickling is dealt with in an efficient manner and the reader who would wish to follow up the condensed information by going to the original work will find the references adequate. Some of the practical aspects of modern descaling methods are included, but some of these (e.g. sodium hydride descaling) have little or no economic application in galvanizing establishments. The properties, compositions and effects of the commonly used fluxes are discussed briefly though with enough detail to allow the knowledgeable galvanizer to obtain some understanding of one of the important fundamentals of this process.

The chapter on galvanizing theory which follows is the most extensive and important in the book. It includes the formation of the coating, the effects of alloying additions to the zinc and the influence of the steel base. The micrographs are very clear, and the author can be complimented on his diagrammatic correlation of the binary iron-zinc equilibrium diagram with the actual phases which can be recognized in microscopic examination.

In the 47 pages devoted to corrosion of the hot-dipped zinc coating, Dr. Bablik includes tables and data by various workers in this field which should prove useful to the technical man in the industry.—MA.

**5.3.2, 1.3, 1.7.1**

**First International Conference on Hot-Dip Galvaniznig.** *Sheet Metals Inds.*, **27,** No. 281, 773-804 (1950) Sept.

An account of the proceedings at the First International Conference on Hot Dip Galvanizing which was held in Copenhagen from July 17 to 21, 1950 and organized by the Hot Dip Galvanizers Association. A full account of the discussions is given together with summaries of the papers presented. The four technical sessions dealt with the following subjects: fundamental aspects of hot dip galvanizing, the heating of galvanizing baths, the relative merits of flux and dry galvanizing and galvanizing residuals and their treatment, the corrosion resistance of galvanized coatings and future prospects for the industry. A complete account of the proceedings at this important conference will be published in due course.—ZDA.

**5.3.2, 5.3.4**

**Aluminum Coated Steel.** *Mech. Eng.*, **72,** 909-910 (1950) Nov.

It has been established that aluminum-coated steel has high rust-resistant properties suitable for industrial and sea coast exposures and has been found superior to steel with galvanized coatings of similar thicknesses. There are two types of aluminum coatings on steel. The first is a surface layer of aluminum-iron alloy, which prevents scaling by oxidation at high temperatures. It is important that the compound should not form to such an extent that the surface becomes brittle and spalls. The second is a surface coating of aluminum to protect the steel from corrosion. There may or may not be an interfacial layer of aluminum-iron alloy which, if present, should be kept to a minimum. Several methods may be used to coat steel with aluminum and each produces its own type of coating with individual characteristics. Four processes are in present-day commercial operation; hot dipping, cladding by rolling, spraying and calorizing. Three other processes have been developed but are not widely used: electroplating, chemical reaction and casting (aluminum around steel, or vice versa, in the Alfin process). Aluminum coatings formed on steel by hot-dipping vary from ½ to approximately 3 thousandths of an inch in thickness, possess good continuity, and a relatively thin interfacial layer. From an operating viewpoint, this process appears to be the most economical. The Armco Steel Corporation in America is now using this method to produce "aluminized" steel sheet on a commercial basis. The process involves preheating the steel in a controlled atmosphere before it enters the aluminum bath. To permit bending and forming of coated products, the brittle interfacial layer must be kept at minimum thickness. This can be accomplished by the addition of silicon to the aluminum-coating bath.—TIME.

**5.3.3.**

**Specifications for Electrodeposited Coatings; Their Purposes and Importance.** CLARENCE H. SAMPLE. *Plating*, **37,** 1140-1142 (1950) Nov.

Discusses types of specifications and importance of tests, early uses of specifications, ASTM-AES and other specifications.—BLR.


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James E. Mavor Company has the men and material to help you solve your corrosion problems, whatever they may be. Men who have spent years in corrosion research and in the development of corrosion prevention products are at your service.

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5.3.4
**The Hot-Dip Galvanizing of Steel.** *Zinc Bull.*, **8**, 8-9 (1949).

A general description of the hot-dip galvanizing, surface treatment and painting of steel window-frames. Some indications are given of the anticipated life under various conditions of exposure.—MA.

5.3.4
**Plating and Metal Spraying: Complementary Processes.** W. E. BALLARD. *Electroplating*, **3**, No. 6, 600-604 (1950) Dec.

Compares and contrasts the two types of coating and gives a few general notes on procedure, with some emphasis on corrosion prevention.—BNF.

5.3.4
**Sprayed-Metal Coating According to Gauchetier Process.** H. REININGER. *Metalloberflache*, **4**, No. 8, A119-A121 (1950).

Particulars on advantages of a metallizing process developed in France. Nature of coatings. Experimental data on effect of oxide content and strain hardening upon hardness and deflection of coatings after various treatments. Recommended machining practices for sprayed-metal coatings. Performance of sprayed coatings in bearings; prevention of peeling of coatings at low temperatures. Reclamation of shafts (with or without slots) and other round-section parts, also semicircular-section parts; suggestions. Practical examples of reclamation of worn parts by spray-coating and spraywelding with steel.

Translation available Henry Brutcher, Box 157, Altadena, Calif.

5.3.4, 1.3
**Metal Finishing Progress in 1950.** W. A. RAYMOND. *Metal Finishing*, **49**, No. 1, 48-54 (1951).

A summary of some of the more important economic and technical advances in electroplating. Theoretical and practical developments in polishing, electropolishing, cleaning, plating, analysis, waste disposal and metallizing are briefly surveyed.—EL.

5.3.4
**Hot-Dip Galvanizing.** *Rev. Gen. Mecan.*, (N.S.), **34**, No. 19, 279-281 (1950).

A brief account of some industrial applications of hot-dip galvanizing, together with some indications of the protection to be expected under various corrosive conditions.—MA.

5.3.4
**A New Way to Metallize.** H. N. ACKER. *Can. Metals, Met. Inds.*, **13**, No. 10, 38, 48 (1950) Oct.

A description of a new powder pistol for metal spraying. The powdered metal is pressure-fed to the gun, instead of being vacuum-fed, and its operation is simplified by using only a single control lever on the gun; other variables being preset at the control panel. An outline of the scope of the metal spraying process is given.—ZDA.

5.3.4
**Coating for Aluminum Protects Metals from Corrosion.** *Am. Machinist*, **94**, No. 24, 154 (1950) Nov. 27.

A process called Pylumin gives an attractive coating with definite corrosion resistance value if no paint finish is applied, and provides an adhesive and efficient base for paint finishes. An immersion process, it employs a single powder whose ingredients have been proportioned and premixed. The solution is maintained by use of a test kit. The costs of installation and operation are low. Ordinary heated steel tanks are all that is required. Unless there is an exceptional amount of grease and dirt on the part, no special cleansing is required. Mfd. by Pyrene Mfg. Co.—INCO.

5.3.4
**Bright Nickel Plating; Some Further Udylite Patents Reviewed.** *Electroplating and Metal Finishing*, **3**, 567-569 (1950) Nov.

Describes recent patent literature concerning anti-pitting and other addition agents for bright plating solutions.—BLR.

## 5.4 Non-Metallic Coatings and Paints

5.4.1
**The Rational Use of Surface Treatment and Coating of Metals.** *Rev. Gen. Mecan.* (N.S.), **34**, No. 19, 278 (1950).

A short account of the Syndicat National du Revetement et du Traitement des Metaux, whose function is to advise on the best protective coating method for any specific purpose and the most satisfactory technical procedure to use.—MA.

5.4.2
**Glass as a Coating for Steel; Some Examples of the Functional Use of Glass-Coating Process.** W. G. MARTIN. *Mech. Eng.*, **73**, 109-113 (1951) Feb.

Described and illustrated.

5.4.2, 3.5.9
**Heat Resistant Ceramic Coatings.** D. G. GENNETT. *Materials and Methods*, **33**, No. 3, 65-67 (1951) Mar.

In general, the purpose of ceramic coatings is either to permit the use of metals at operating temperatures higher than normally possible or to prolong their useful life at conventional operating temperatures. Primary attention is directed here toward the protection from corrosion (principally oxidation) of strategic iron and steel and their alloys at operating temperatures higher than organic coatings can withstand. Coating applications, requirements and test results are thoroughly discussed and illustrative graphs are presented.—TDD.

5.4.3, 7.6.9
**Blast Furnaces Operate With All-Carbon Linings.** G. D. ELLIOT. *Iron Age*, **166**, 88-91 (1950) Sept. 21.

Describes experiences of Appleby-Frodingham Steel Co. (England) which have shown many advantages of carbon brick as a blast-furnace refractory. Includes diagrams and graphs.—BLR.

5.4.2, 3.5.9
**High Temperature Resistant Ceramic Coatings for Iron, Steel and Alloy Metals.** DWIGHT G. BENNETT. *Finish*, **8**, 31-35+ (1951) Jan.

Reviews, correlates and summarizes results of work on the above by various organizations. Typical data are charted; test equipment is diagrammed and illustrated.—BLR.

5.4.3
**Linings for Plating Tanks.** *Electroplating*, **3**, No. 5, 574-575+ (1950) Nov.

Relative merits of polyvinyl chloride, perspex, polythene, rubber, asphalt and vitreous enamel linings for steel plating vats. Paint not recommended. General advantages of inert linings.—BNF.

5.4.5
**A New Plastic for Coatings.** G. W. CORNISH. *Org. Finishing*, **1946**, No. 3, 26-30, Mar.

The use of polyethylene plastics for phenolic compounds to improve their service life.

5.4.5
**Film-Type Anti-Rust Compound.** *Oil Gas J.*, **49**, No. 42, 217 (1951) Feb. 22.

A film-type anti-rust compound named Gulf No-Rust No. 6, has been developed by Gulf Oil Corp. The new compound will provide approximate surface coverage of 390 sq. ft. per gal, and is used for protection of metal surfaces exposed to corrosion either indoors or outdoors. The film is applied by dipping at 70°F., dries in four hours and has a thickness not greater than 8/1,000 in. Gulf claims that the compound does not separate on storage and that the coating does deteriorate between 0° and 190°F.

5.4.5, 7.5.5
**Tested Tank Coating Now Available to Marine Industry.** *Marine Eng. & Shipping Rev.*, **55**, No. 12, 111-112 (1950) Dec.

The corrosion of tank and ship plates can be checked by a new but long tested tank coating which will not affect the water. The coating "Pero-Kote," is a cold-applied plasticized gilsonite with mineral fiber reinforcement. The coating is guaranteed 5 years when applied according to direction. It can be brushed or sprayed with the ease of an enamel at normal temperatures and worn spots can be touched up or a new coat applied over the old. Pero-Kote is toxicologically innocuous and shows no detrimental effect from chlorine solutions. Temperatures as high as 400°F. or below freezing will not cause it to run or crack. Manufactured by Perolin Co., Inc.—INCO.

5.4.5, 5.4.8, 8.4.3
**Tougher Coatings for a Tough Job. Coatings Based on Vinylite Resins Combat Well-Head Corrosion in Galveston Bay Fields.** J. E. KASTROP. World Oil, Editorial Staff. *Bakelite Rev.*, **22**, No. 2, 12-15 (1950) July.

Vinyl resin coatings appear to be effective in controlling salt-water corrosion of submerged well-heads employed in underwater oil and gas fields. The films are permanently thermoplastic, neutral, nonoxidizing, nonheat-reactive, insoluble in alcohol, grease, oils, and aliphatic hydrocarbons and are not attacked at normal temperatures by alkalies or mineral acids.

The protective film is applied first to the above-water part of the well-head assembly after thoroughly cleaning the metal. Rust and other foreign materials are best removed from irregularly shaped surfaces by sand blasting. The first coat is a Vinylite resin WP-1 'wash primer,' an alcohol solution of polyvinyl butyral resin pigmented with an insoluble zinc chromate. With the addition of phosphoric acid, the primer forms a complex metal-resin phosphate film at the metal interface and penetrates into

cavities and corrosion pits. A film 0.3-0.5 mil thick is adequate. This coat is followed by two coats of an anti-corrosive primer consisting of Vinylite resin VAGH, red lead pigment, methyl isobutyl ketone solvent, toluene diluent and a plasticizer. The three primer coats are followed by three finishing coats that contain Vinylite resin VYHH, a copolymer consisting of 87 percent vinyl chloride and 13 percent vinyl acetate; this proportion gives a suitable balance between chemical resistance, solubility, and film toughness. Each coat of the primer and of the finishing film is allowed to dry for at least 1 hr. A minimum total film thickness of 5 mils should be obtained.

The underwater surfaces of the wellhead assembly are sandblasted and coated while it is submerged; this portion of the assembly is first encased in a metal box and the water is pumped out. In the future, new wells can be coated before installation. The primer coats are applied as on the above-water surfaces, but instead of the three normal finishing coats, the underwater surfaces of the assembly are covered with two heavy coats of a vinyl resin antifouling paint containing cuprous oxide, which is toxic to minute fouling organisms. The paint is formulated in such a way that the water will slowly penetrate the outer layers and dissolve the oxide.—PDA.

5.4.5

**Use of Styrene in Protective Coatings.** T. H. GLYNN MICHAEL. *Am. Paint J.*, **34,** 60+ (1950) Aug. 28.

Covers chemistry of styrenated oils and alkyds, their characteristics, and properties imparted by them to coatings. —BLR.

5.4.5

**Paint for Paper-Board and Sheet-Metal Roofing Materials.** A. W. RICK. *Lack—u. Farben-Chem.*, **4,** No. 1, 19-22 (1950).

The requirements of paints for coating and restoring roof-covering materials are discussed. Bituminous paints, the formulation of which must be adjusted to the work required, give the best results and maximum durability.—RPI.

5.4.7

**Modern Masking Materials and Methods for Fabrication and Spray Finishing. Part IV. Liquid Masking Materials and Peelable Plastic Coatings.** A. P. SCHULZE. *Products Finishing*, **1950,** 44-62, Nov.

For some spray finishing purposes, liquid masking materials applied by brush or spray offer advantages not found in pressure-sensitive tapes of metal masks. Materials of this nature are discussed as to their characteristics and applications in this final part of the article. Peelable plastic coatings are also applied by spraying to polished sheets which are to be formed and drawn. The plastic film protects the sheet from die marks and can be peeled off the product after its fabrication. The third general use for liquid masking materials and peelable plastic coatings discussed in this article is that of coating paint-spray booth walls to facilitate periodic maintenance and cleaning operations. A number of products used for this purpose are described and discussed and a number of references to the literature are cited.—TDD.

5.4.7, 7.5.5, 8.4.3

**An Anti-Corrosion System Consisting of Five Coats of "Vinylite" Resin-Based Paint.** *Plastic News Letter*, **11,** No. 13, 3 (1951) Mar. 26.

The above is being used by a major oil company to coat 24 of its giant, steel oil storage tanks. The coating resists corrosion from weather, water and most chemicals, and the base material also resists breaks in the coating caused by constant working and buckling of steel plates. Test applications are still in good condition after six years' exposure to the same conditions to which the oil tanks are subjected.

5.4.7, 8.1.2

**Preparing Metal Surfaces for Painting.** Ministry of Works. Advisory Leaflet, 1950, No. 11, 3pp.

Practical methods for the preparation of surfaces for painting are described with special reference to metals commonly used in building, e.g., iron, steel, aluminum, zinc, copper and lead. General rules for the treatment of dirty, corroded and smooth metal surfaces are given. The removal of mill scale from iron and steel and the careful choice of primers is stressed.—RPI.

5.4.7

**Flame Sprayed Plastic Coatings.** B. GOLDBERG. Ferro-Co Corp. *Corrosion*, **7,** No. 2, 47-50 (1951) Feb.

The history of flame spraying is briefly reviewed. Both guns and powder containers used for applying flame-

Corrosion —AN ALLY OF THE ENEMY

CORROSION — the great saboteur — works night and day making old storage tanks useless and necessitating costly repairs to new. In some sour crude areas, new tanks have been rendered useless in as little as 18 months.

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sprayed coatings of plastic powders are described in some detail. Necessary criteria for organic materials both thermoplastic and thermosetting are indicated. Problems involved in producing suitable powders of tough nonfriable resins are discussed and indications given of several promising solutions. Properties of flame-sprayed Thiokol coatings are reviewed in some detail. Recent work on improvements in flame-spraying technique is illustrated by a discussion of the advances in the flame-spraying of various polyethylene compounds. This includes comments on current theory, various fuel-gas combinations and polyethylene compounding for obtaining specific properties in flame-sprayed coatings. Some data are presented on the effect of after-treatments of flame-sprayed plastic coatings. Experimental work being done on producing flame-sprayed coatings of fluorinated hydrocarbons is described, and a preliminary report given on the properties of these coatings. Recent developments in the technique for producing smooth nonporous coatings of hot-melt composition are discussed in some detail. In an attempt to indicate how the corrosion engineer can evaluate the suitability of flame-sprayed plastic coatings for a particular corrosion problem, the history of several successful applications is reviewed.—TDD.

5.4.7

**Finishes Successfully Baked on Nonferrous Products by Induction Heating.** F. NETSCHERT. *Materials & Methods,* **32,** No. 3, 60-61 (1950) Sept.

Induction heating is being used successfully to bake and cure synthetic enamel finishes on aluminum and brass builders' hardware products by the Technical Glass Co. of Los Angeles. In duction heating has advantages over infra-red or gas oven baking including: 1) high uniform product quality; 2) adaptability to various uses; 3) ideal shop working conditions; 4) low maintenance and operating costs. During a production run, 288 workholders spaced 2¼ in. apart on a 55 ft. continuous chain conveyor move in front of automatic spray guns and then into a filter air tunnel which prevents contamination and allows adequate "flow out" time for the removal of excess solvents. The conveyor then passes through the baking chamber containing a channel-type induction coil, which is energized by the 15 KW, 10,000 cycle Tocco power unit. The enamel is baked uniformly since voltages are generated in the metallic object and the enamel in contact with the metal surface is baked first so that gases are expelled. A constant temperature can be maintained throughout the baking. The quality of product obtained is demonstrated by the fact that plated aluminum products are sold with a ten-year guarantee for service under normal conditions. Induction heating baking requires less floor space than the other methods and offers a minimum of heat with no glare or fire hazard to endanger the safety of employees. The economy of the process is found in the saving of power, adaptability to mass production techniques, time saving operations, minimum of space, labor and number of rejects.—ALL.

5.4.7

**Better Coat Paint Saved in Hot-Spray Process.** *Sci. News Letter,* **58,** No. 4, 57 (1950).

A system of hot spraying is briefly described. The paint is continuously circulated through the heating chambers and the spray gun.—RPI.

5.4.7, 6.6.5

**Bituminous Protective Coatings for Concrete—Have They Stood the Test?** A. W. RICK. *Bitumen, Teere, Asphalte, Peche,* **1,** No. 10, 257-259 (1950).

A discussion of the value of bituminous cladding for concrete and the causes for its eventual failure on weathering.—RPI.

5.4.8

**Report on Various Types of Protective Coatings.** Vereinigte Lackfabriken, Hamburg. Board of Trade, Tec. Inf. and Docs. Unit, FD. 194/50, PB. 22818 and 22823-5, 17 Frames.

Reports on the following types of coatings are included: insulating coatings for electric meter coils, a section being included on the subject of vacuum impregnation; oil- and petrol-resistant coatings for concrete tanks and for concrete floors (including the necessary preliminary treatment for new surfaces); a corrosion-, weather- and sea-water-resistant temporary coating for metal articles during transit.

5.4.8, 3.5.9

**High Temperature Heat Resistant Organic Coatings.** A. G. GRAY. *Products Finishing,* **15,** No. 2, 68-80 (1950) Nov.

An account of a paper presented at the recent Cleveland meeting of the Electrochemical Society by R. A. Williams, I. H. Lutz and W. H. Hayne. These workers have developed a paint system which will stand prolonged exposure to temperatures above 800° F. The various experimental systems are described, with notes on their performance. The best finish found was the following two-coat system. The primer consisted of a stoving heat reactive phenolic varnish pigmented with a mixture of zinc, cadmium and aluminum powders. The top coat was a mixture of glyceryl phthalate and silicone DC 802 pigmented with aluminum, baked at 300° F for not less than two hours. The paint system withstood heating at 800° F for over 300 hours with no failure, and was not harmed by heating in oil or toluene for short periods.—ZDA.

5.4.8, 7.4.2

**Examination of "Luphen" Lacquers.** Brauns. Board of Trade, Tech. Inf. & Docs. Unit, FD, 456/50, 1 p, 1-9 Frames.

These lacquers, which are based on phenol/formaldehyde resins, were examined as anti-corrosive coatings for cooler tubes. Brush-applied coatings did not give satisfactory protection.—RPI.

5.4.8, 8.9.5

**Protection of Ships by Paint.** *Brit. Ind. Finishing,* **2,** No. 25, 886-888+ (1950); **3,** No. 26, 59+; No. 28, 258-262.

A detailed account is given of the various techniques used in painting the different parts of a ship, with particular emphasis on the hull. The various types of fouling growths such as seaweed, shell-like organisms (e.g., barnacles), tunicates and, in the case of wooden vessels, marine wood-borers and the methods of their control by the use of paints containing mercury, copper and organic poisons, are described. Considerable importance is attached to the proper preparation of under-water surfaces before painting, particularly the removal of mill scale, grease, rust, etc., and in this connection the advantages accruing from pickling are mentioned. The first coat of paint on the bare metal should always be brushed and never sprayed; full details of spray painting technique used for the later coats are given. The treatment of the stern with an anti-galvanic black paint to prevent the electrolytic corrosion caused by the cell set up between bronze propellers and steel hulls is described. The boottop should always receive an adequate painting treatment (e.g., priming followed by two coats of a special composition), since it is continually exposed to alternate wet and dry conditions. Other parts dealt with include topsides, holds, woodwork, decks, coal and oil bunkers and water tanks.—RPI.

5.4.8, 4.3.1

**Coating that Resists Acids and Alkalies.** *Machinery,* **57,** No. 3, 182 (1950) Nov.

Carclad, a finish having a Vinylite resin base provides long life and resistance to the corrosive effects of acids, soda ash, sulfur alkalies, phosphate, sodium chloride and cement on railroad hopper cars and similar equipment. Manufactured by Sherwin-Williams Co.—INCO.

5.4.8

**Rust-Inhibiting Paint Can be Applied Over Corroded Surfaces.** *Machinery,* **57,** No. 3, 183 (1950) Nov.

A new rust inhibiting oil-base paint for maintenance applications, Certified Rust Inhibitor No. 425, serves as a rust preventive and finish coat in one application over damp as well as dry surfaces. This paint is resistant to fumes, salt air, and dry heat up to 500° F, and can be applied to either new or rusted metal. Mfd. by United Laboratories, Inc.—INCO.

5.4.8, 3.5.9

**Heat Resistant Coatings.** E. J. BROMSTEAD. *Org. Finishing,* **11,** No. 9, 36-38 (1950) Sept.

A review of the available vehicles and pigments for heat resistant finishes. The following are included among the pigments which have suitable heat-stability: zinc dust; zinc oxide; cadmium selenosulphide (red); and cadmium yellow.—ZDA.

## 5.6 Packaging

5.6.1, 8.10.4

**Army's New Methods for Export Shipping.** V. V. KOWOROWSKI. *Flow,* **7,** No. 7, 136+ (1951) May.

The armed services have benefitted in many ways from the experiences gained during the last war. Thousands of production manhours were wasted because critical parts arrived in useless condition. But with more and more goods again being shipped to far-flung areas, the army has doubled its efforts to make sure that goods now reach overseas depots in the same condition as when they left inspection departments in the U. S. plants or depots. The four methods which were developed and ap-

proved by army ordnance in conjunction with other services, government agencies, and industry are illustrated. Each method is broken down into the various packaging steps.—TDD.

5.6.1, 3.2.3, 6.3.10

**Tarnishing of Nickel-Silver.** A. L. SIMMONS. *Metal Progress,* **58,** No. 3, 345-347 (1950) Sept.

The tarnishing or corrosion of metal articles can be minimized by adopting these precautions. On no account should unseasoned timber be used for packing cases. Use of hardwoods should be avoided. Articles should be packed in a warm, dry atmosphere and the contents of cases hermetically sealed—that is, in heat-sealed, waxed or other impervious paper, or in soldered metal linings. Packers should wear cotton gloves to avoid fingerprinting the articles. Cellophane should not be relied upon as a protection against moisture.—INCO.

5.6.3

**Aluminium Foil Proves Practical for Packaging.** JOSEPH GESCHELIN. *Automotive Ind.,* 102, No. 8, 41+ (1950).

The use of embossed aluminum foil, in very light gauges, for the packaging of finely finished machine parts is described. Aluminum foil, when used on ferrous parts, affords mechanical protection and prevents corrosion by means of a cathodic action. The foil provides a positive barrier to grease, oils and water, and in some cases the use of foil packaging makes corrosion-preventing oils unnecessary.—MA.

5.6.3

**Storage Protection of Metal.** J. F. STIRLING. *Practical Engr.,* **22,** No. 545, 16-18 (1950).

A number of well-known corrosion preventatives for the temporary protection of metallic components are described.—MA.

5.6.3, 5.8.2

**Volatile Corrosion Inhibitors-New Rust Preventatives May Revolutionize Ordnance Packing.** G. FOSTER. U.S.A.F. *Ordnance,* **35,** No. 182, 158-160 (1950) Sept.-Oct.

Volatile corrosion inhibitors are among the most promising of the new materials developed for the protection of metals against corrosion. Dicyclohexylamine nitrate is essentially used for ferrous metals. The Ordnance Corps is engaged in developing new packaging procedures, utilizing these inhibitors, that will enable it to deliver weapons to the combat zone that can be used upon removal from the container.—INCO.

5.6.3

**Corrosion Proofing.** *Rev. Sci. Instruments,* 21, No. 12, 1033 (1950) Dec.

Ferro-Pak is a packaging paper which is treated on both sides with a volatile corrosion-inhibiting chemical to afford protection for ferrous articles wrapped in the paper. The wrapped product is ready for use without cleaning when the paper is removed. The coating evaporates slowly and does not flake off or stick to the wrapped product. Protection is maintained with the paper either wet or dry and can extend into years. Sheets or rolls are regularly supplied and bags, pouches or shrouds can be made to order. Manufactured by Cromwell Paper Co.—INCO.

5.6.3, 8.9.1

**Hermetic Sealing of Aircraft Instruments.** R. F. BUCKLEY. General Electric Co. *Gen. Elec. Rev.,* **53,** No. 11, 43-45 (1950) Nov.

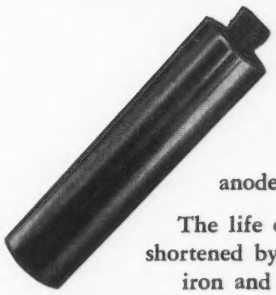
Extended use of aircraft and their required flight in all types of weather increases the importance of maintaining instrument reliability and accuracy by protection against adverse atmospheric conditions. This article shows how hermetic sealing is advantageously used to give such protection. The hermetically sealed case is the most practical method of providing complete protection against adverse ambient conditions. As described and illustrated here, the hermetically sealed case design, incorporating as its main section a one-piece tube, has met Air Force and Navy sealing and climatic test requirements. The following are some of the advantages of hermetic sealing found in this case design: simple construction, small size, longer instrument life, reduced maintenance, greater instrument reliability, elimination of window-glass fogging, lower temperature rise, decreased windage losses for rotating parts, and higher electrical breakdown potential.—TDD.

5.6.3, 6.4.2

**Aluminium Foil Finds New Uses as a Packaging and Insulating Material.** KENNETH ROSE. *Materials & Methods,* **30,** No. 1, 63-65 (1949).

Brief reference is made to the use of aluminum foil containers for good packages and of laminates with paper or plastic backing for labels, food pack-

*Anodes look alike too..*



All fingerprints look alike at first glance . . . but a magnifying glass will show many differences. Anodes look alike too, but a spectrograph can also point out marked differences in anode purity.

The life of many anodes on the market today is shortened by use of metal impurities such as nickel iron and copper. An impure anode *may* deliver the same amount of electrical current as one of high purity, but its length of service is shortened. This leads to the unnecessary spending of hundreds or thousands of dollars for replacement of prematurely expended anodes.

At Standard Magnesium foundries, *spectrographic analyses* are made to inspect the quality of the anode and keep impurities at a minimum. A certified *spectrographic analysis* is furnished with each shipment, insuring you of the best economical protection at lowest cost.

You're sure it's pure when you buy from . . .

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TULSA, OKLAHOMA

129

ages and the packing of radio and aircraft parts.—MA.

5.6.3, 1.7.1

**Eleven Oil-Type Temporary Metal Protectives.** *Engineering,* **171,** 79 (1951) Jan. 19.

Field and laboratory tests by the British Chemical Research Lab. in collaboration with the Institute Petroleum as reported in the 1949 Report of the Chemistry Research Board. A rubber-latex film was developed in which 5 percent sodium benzoate and 0.4 percent sodium nitrite are added to natural or vulcanized latex. This film is effective in protecting steel, cast iron, aluminum, etc., and is commercially available. Wrapping papers for steel, impregnated with 3 percent sodium benzoate and 0.25-1.5 percent of sodium nitrite were found to give excellent corrosion protection, provided the chlorides present in the paper were below 0.05-0.1 percent, depending upon the amount of nitrite.

## 5.7 Treatment of Medium

5.7.3, 4.6.2

**Degassing of Water to Reduce Corrosion. IV.—Experiments on the Oxidation of Sodium Sulphite by Molecular Oxygen in Condensates and Natural Waters.** K. WICKERT AND E. IPACH. *Werkstoffe u. Korrosion,* **1,** No. 3, 107-110 (1950)—Cf. *Arch. Metallkunde,* **3,** 105 (1959).

Experiments show that the reaction between sodium sulfite and molecular oxygen in solution can be catalyzed. Of the accelerators tried: 1) Potassium permanganate is the best in neutral waters, and its action is independent of the neutral salt content; it is less effective in alkaline waters; 2) Metallic copper gives the best results with condensate; and 3) The acetic acid complex of copper gives a high rate of reaction in neutral solutions, whether natural waters or condensate. The commercial applications of the results are discussed.—MA.

5.7.7, 4.4.8, 8.4.2

**Corrosion in Amine Gas Treating Plants.** F. C. RIESENFELD AND C. L. HUGHES. The Fluor Corporation. *Petroleum Refiner,* **30,** 97-106 (1951) Feb.

Amine solutions are extensively used in process plants for the removal of acidic gas components from petroleum hydrocarbons. Among the various operating problems of glycol-amine gas treating plants one of the most serious is the corrosion of carbon steel which is generally used for the manufacture of process equipment.

From the evidence accumulated to date it appears that there are two general means of successfully attacking the problem of corrosion of carbon steel equipment in amine gas treating plants. In glycol-amine treating plants by adopting certain process adjustments and operating conditions, such as solution temperature in the hottest pass of the heat exchangers, degree of saturation of the solution and elimination of sources of oxygen, corrosion of heat exchangers can be reduced materially. In aqueous amine systems by maintaining the proper reboiler temperature and preventing oxygen contamination of the solution, corrosion can be controlled to an appreciable extent. Neutralization of corrosive contaminants and reactivation of inactivated amine by the addition of strong inorganic bases and steam distillation was also found beneficial. No conclusive evidence is available as to the effectiveness of corrosion inhibiting agents.

The experiments reported in this paper indicate that aluminum 3 sulfur and 14-6 chromium-½ molybdenum steel are suitable materials for use in heat exchangers in glycol-amine plants, while 304 and 316 stainless steel, Monel, Inconel and Carpenter 20 steels have shown good resistance to corrosion in aqueous amine systems operating at various conditions. The use of alloys will effectively reduce corrosive failure in most cases while permitting maintenance of plant operation at optimum conditions.—UOP.

5.7.7, 4.6.13

**Acid Chemical Wastes Made Harmless by Automatic Lime Slurry Neutralization.** *Eng. News-Record,* **146,** 47-48 (1951) Jan. 25.

Describes and diagrams equipment for the above at the Towanda, Pa., plant of Sylvania Electric Products. The acid wastes are given off in the manufacture of chemical and metal products by the Tungsten and Chemical Division.—BLR.

5.7.7, 8.4.3

**Control of pH in Stills with Boiler Blowdown Water.** *Petroleum Refiner,* **30,** No. 2, 90-91 (1951) Feb.

Corrosion control in the natural gasoline plant of the Wilmington Gasoline Co., at Terminal Island, Calif., by use of boiler blow water in the distillation system to maintain the pH at 6.5 to 7.5 is described.

## 5.8 Inhibitors and Passivators

5.8.2, 8.10.4

**Fuels and Lubricants Needs Listed by Army.** B. S. MESICK. U. S. Army. Paper before API, Div. of Marketing, Los Angeles, Nov. 1950. *Petroleum Refiner,* **29,** No. 12, 88-92 (1950) Dec.

Discussion of specifications for fuels, engine oil, greases and hydraulic fluids for military use. Improved oxidation inhibitors and metal de-activators in gasolines, improvements in compatibility and better low-temperature characteristics in diesel fuels and the development of one corrosion preventive of universal application are needed to meet military requirements. The improvement needed in gear oils is better corrosion resistance and the ability to prevent corrosion in the presence of small amounts of moisture. Illustrations.—INCO.

5.8.2, 4.3.2, 8.8.5

**Urea-Formaldehyde Pickling Inhibitors.** *Electroplating,* **3,** No. 15, 565 (1950).

A short summary of two recent patent claims for the production of pickling inhibitors by the condensation of urea and/or thiourea (with or without sulphite pulp waste liquor present), with formaldehyde: the inhibitors to be used in pickling solutions containing 1-50 weight-percent of sulfuric, hydrochloric, or hydrofluoric acid. An inhibitor concentration of 0.025 weight-percent is recommended, but it is claimed that 0.001 percent is effective in pickling steels, iron, stainless steel, tinned steel, tinned copper and tin.

5.8.2, 4.6.4

**Corrosion Control for Cooling Systems of Electric Apparatus.** E. J. REMSCHEID. *Gen. Elec. Rev.,* **54,** No. 3, 36-40 (1951) Mar.

The addition of sodium chromate to the water used in cooling systems for power rectifiers and other electrical equipment of essentially iron construction is recommended to prevent corrosion.

5.8.2, 8.4.3

**New Inhibitor for Sulfide Corrosion.** J. A. CALDWELL. Humble Oil & Refining Co. *Oil Gas J.,* **49,** No. 40, 95-97 (1951) Feb. 8.

A new inhibitor for sulfide corrosion in producing oil wells, which is a non-toxic, free-flowing liquid, with very little odor has been developed and placed on the market under the trade name of Corexit. The inhibitor is injected into the annulus between tubing and casing so that it goes to the bottom of the well and travels up the tubing to the surface with the produced fluids. Use of the inhibitor in several wells has greatly reduced tubing corrosion. Figures given.—INCO.

5.8.2, 7.4.1

**Use of Sodium Benzoate as an Antifrigerant and as a Corrosion Inhibitor in Heat Exchange Systems.** *Fruit Products J.,* **28,** No. 308, 317 (1949) June. *Can. Chem. Process. Inds.,* **33,** No. 960 (1949) Nov.

Experimental work indicates that sodium benzoate is superior as an antifreeze in engine cooling systems in that it inhibits corrosion and represses rust and scale removal. The same advantages are obtained when the compound is added to solutions of glycol or glycerine to produce concentrations of 1.5 percent sodium benzoate.—RA.

5.8.2, 8.9.3

**New Corrosion Inhibitor Gets Job Done.** K. T. FELDMAN AND F. M. WATKINS. Sinclair Refining Co. Paper before API Subcom. on Products Pipe Line Tech., St. Louis, Sept. 1950. *Oil Gas J.,* **49,** 340-344 (1950) Nov. 16.

Report of results of use of RD-119 to prevent corrosion in the interior of products pipe lines includes laboratory control tests, mechanism of inhibitor action, advantages of RD-119 and pipe line experiences and test results.—INCO.

5.8.2, 4.4.7

**Additives Adapt Lube for More Jobs.** *Power,* **94,** No. 11, 87-89 (1950) Nov.

A description of what additives are, why they are used, and what they do. Lube additives are specific chemical compounds added to oil to alter one or more of its specific chemical or physical properties. Discussion covers lubricity agents, oxidation, rust inhibitors, V-I improvers, detergent additives, and defoaming agents. Some inhibitors have already become more important than the oil itself. Certain properties of petroleum oils make them rather limited in usefulness in this role of a carrier. Hence in the future, additives will most likely be used more in combination with the new synthetic oils.—INCO.

5.8.3

**Competitive Adsorption from Solution Between Hydrophobic and Hydrophilic Molecules and Ions.** R. L. MERKER AND W. A. ZISMAN. Paper, A.C.S. Colloid.

Chem. Div. Symp. on Surface Chemistry in Corrosion, 119th Meet., Cleveland, Apr. 9-12, 1951; Abstr. of Papers: 19G.

By considering the variation in concentration with pH of water-soluble amines and their ions in aqueous solution, it is shown that hydrophobic films on platinum are primarily due to the adsorption of free amine in the more alkaline regions of the pH scale. In the less alkaline regions hydrophobicity is due to the adsorption of amine ion. A similar situation exists in the case of water-soluble carboxylic acids.

5.8.3, 5.8.4, 2.3.4

**Inhibition of Corrosion by Organic Nitrogen Compounds.** G. ANTONUCCI. *Pitture e Vernici*, **5**, No. 9, 379-380; No. 11, 473-476; No. 12, 515-517 (1949); **6**, No. 1, 15-18; No. 2, 53-54 (1950).

The inhibitive power of a large number of amines has been determined by measuring the loss in weight of pieces of iron after immersion for 46 hours in normal sulfuric acid containing the inhibitors. The difference between the loss in weight in a solution containing the inhibitor expressed as a percent of the loss of weight in the control solution is called the anticorrosive efficiency. Different amines are compared by plotting the anticorrosive efficiency against their concentration in the solution expressed in terms of normality. Inhibitive power is found to depend mainly on the stereochemical properties of the amine, i.e. the area of the metal which can be covered and protected by a single adsorbed molecule, and not on the dissociation constant. Since the nitrogen atom is responsible for adsorption, by varying the positions of nitrogen atoms in the molecule it is possible to modify the inhibitive properties and thereby obtain high inhibitive power. Some typical figures for anticorrosive efficiency are as follows: (at 0.25 percent methylamine 20, ethylamine 25, propylamine 45, dimethylamine 55, diethylamine 45, dipropylamine 72, trimethylamine 92, triethylamine 87, tripropylamine 96, aniline 40, methylaniline 82, ethylailine 78, propylaniline 92, dimethylaniline 70, diethylaniline 92, p-toluidine 64, O-toluidine 66; (at 0.1 percent) aniline 22, p-toluidine 50, m-phenylenediamine 41, -naphthylamine 83, -naphthylamine 83.5; (at 0.05 percent) 2-amino-1-phenylazo-naphthalene 92, 4-amino-1-phenylazo-naphthalene 91.1, 2-amino-1-( toluylazo)-naphthalene 97.4, 2-amino-1-( amino-phenylazo)-naphthalene 98.8.—RPI.

5.8.4, 4.6.11

**Sodium Nitrite as an Inhibitor Against the Attack of Sea Water on Steel. Part 1—The Influence of Sodium Nitrite on the Area and Intensity of Attack.** D. WYLLIE AND G. C. N. CHESMAN. *J. Soc. Chem. Ind.*, **68**, No. 6, 165 (1949).

Prevention by sodium nitrite of attack of sea water on steel studied in two ways. Observation of extent and nature of corrosion of mild-steel specimens partially immersed in sea water containing nitrite. Measurement of corrosion currents using divided cell. Appearance of widespread brown discoloration on steel at higher nitrite concentrations discussed and catalytic mechanism suggested for inhibiting action of nitrite. Effect of mixing phosphates and nitrite reported.

5.8.4

**Oxygen-Containing Organic Inhibitors of Corrosion.** C. CHEH, Ph.D. Thesis, Univ. Minnesota (1939). *Summaries of PhD. Theses, Univ. Minnesota*, **3**, 193-195 (1949).

The corrosion-inhibiting efficiency of over 60 oxygen-containing organic compounds, including ethers, acids, alcohols, esters, aldehydes and ketones was investigated. The following are some of the generalizations observed: compounds containing a carbonyl group were good inhibitors; within a homologous series of keytones and esters, the inhibitory efficiency increased with increase in length of carbon chain; within an aliphatic aldehyde series at lower inhibitor concentrations, the lower members gave better inhibitory value; unsaturated compounds were generally more effective below equilibrium concentration, whereas above equilibrium concentration, saturated compounds were usually superior, polymerized compounds that have larger molecular structure should give better results, providing there is no change in the activity of the original active (carbonyl) group of the compound after polymerization. A fairly good inhibitor was obtained by making a higher molecular weight aromatic diketone (anthroquinone) more soluble in normal sulfuric acid solution through the introduction of a sulfonic acid group into the structure. The higher acidity of a sulfonic acid seems to be unfavorable for inhibitor action.

5.8.4, 2.3.4

**Testing of Organic Chemicals with Corrosion Inhibiting Properties.** E. R. LAMSON. U. S. Naval Air Material Center, Philadelphia. Report AML-NAM-AE 424, 508, Part III, Jan. 1950.

Experimental data are reported on the use of high molecular weight, straight chain, organic compounds as corrosion inhibitors in various oils and in microcrystalline wax. These compounds were generally less effective than the reference standards. Of the straight chain acids examined in a naphthenic base oil, erucic acid (cis-13-docosenoic acid) was the most effective. The effectiveness of the soaps varied and all increased the viscosity. Only 1 percent calcium cerotate (calcium hexacosanate) gave better protection than sodium oleate, the standard reference for this group. The esters and salts of sulfonic acids were not appreciably effective. Armid RO, a mixture of amides of unsaturated fatty acids gave good inhibiting effects in microcrystalline wax. Diethyl lauramide and diethyl stearamide were the least effective of the amides.

5.8.4

**Molybdates and Tungstates are Comparable to Chromates as Corrosion Inhibitors.** W. D. ROBERTSON. *Chem. Eng. News*, **28**, 3769 (1950) Oct. 30.

Data presented at the Electrochemical Society meeting at Buffalo, Oct. 11-13, 1950.

## 5.9 Surface Treatment

5.9.1, 6.3.19

**Finishes for Zinc.** *Die Castings*, 8, No. 5, 49-50 (1950).

A brief review of the various finishes available for zinc alloy die castings. Barrel polishing is done in four stages, tumbling, deburring, rolling and burnishing; buffing and polishing are other methods of mechanical finishing. Organic finishes are used to give color, protection and texture to the die casting, while chromate, nickel or phosphate chemical treatments are available to prevent tarnishing of the surface. Plating, usually chromium on copper and nickel, is another widely used finish for die castings. —RPI.

5.9.1, 5.3.4, 5.9.4

**Metal-finishing Processes.** G. E. GARDAM. *Times Rev. Ind.*, **4**, No. 43, 20-22 (1950).

The various industrial methods of applying protective coatings are briefly described. Considerable attention is paid to the electrolytic and mechanical application of metallic finishes and the associated preparation of the underlying surfaces. The various chemical coating processes, including anodizing and phosphatizing are also discussed. A brief section on paint coatings and vitreous enamels is also included.—RPI.

5.9.1, 1.7.1, 5.4.8

**Surface Preparation and Repainting of Structural Iron and Steel.** A. J. EICKHOFF. *Proc. Am. Soc. Testing Materials*, **49**, 311-317 (1949).

The final report of a sub-committee of ASTM Committee D-1. Two-paint systems were applied over three types of surface mill-scaled, rusted and sandblasted, after no pretreatment or one of three phosphoric acid treatments. Repainting tests were also carried out over systems which had failed to varying extents. Conclusions reached were 1) Repainting in an industrial atmosphere should be carried out when the film is in a better condition than that which would be tolerated in a rural environment; 2) Painted sandblasted panels allowed to rust were less difficult to protect on repainting than painted mill scale panels allowed to rust; 3) None of the three pretreatments were significantly better than no treatment at all; 4) There was a significant difference between the performance of the two paint systems; 5) A second pretreatment at the time of repainting did not materially improve performance.—ALL.

5.9.1, 1.3

**Elements of Metal Cleaning—For the Fabricator.** ADOLPH BREGMAN. *Metal Progress*, **57**, No. 1, 75-78 (1950).

A general review.—MA.

5.9.1, 1.3

**Metal Cleaning.** M. REEVES. *Metal Ind.* (London), **77**, No. 4, 54-55 (1950) July 28th.

A review of methods for the surface preparation of metals prior to finishing. Rust may be removed by grit blasting or by a liquid cleaner based on phosphoric acid. Degreasing may be carried out by emulsion cleaners, which have the advantage of simplicity, or by trichorethylene or other solvents, which are usually applied to the work as vapors. Such methods are suitable for mechanical operation. A note on high pressure jet cleaners concludes the review.—ZDA.

5.9.1, 6.4.2

**Preparation of Aluminium and Light Aluminium Alloy Surfaces Before Painting.** H. RABATE. *Trav. Peinture*, **5**, No. 3, 119-120 (1950).

The various treatments (solvent, basic, and acidic degreasing, abrasion and sandblasting, chemical and physical oxidation) adopted for removing grease from aluminum or aluminum alloy surfaces and preparing them for painting are described.—RPI.

5.9.2, 1.2.2

**New Process Slashes Cost of Phosphoric Acid Pickling.** C. F. PAULSON AND M. E. GILWOOD. *Iron Age*, **166**, No. 24, 97-99 (1950) Dec. 14.

5.9.2, 5.3.4

**Activation of Metal Surfaces Preparatory to Being Electroplated.** N. B. BALASHOVA, YU. S. TSAREVA, AND A. T. VAGRAMYAN. *Doklady Akad. Nauk SSSR*, **71**, No. 1, 73-75 (1950).

Study of condition of surfaces to be electroplated (i.e. whether active or passive) by a procedure originally developed for determining the rate of passivation during the electrodeposition of metals. Experimental procedure and results. Activation of surface to be plated, i.e. freeing it from oxides and surface-active substances in cyanide-containing solutions, studied on the basis of copper and silver electrodes. Effect of potassium cyanide vs. ethyl alcohol. Translation available Henry Brutcher, Box 157, Altadena, Calif.

5.9.2, 8.5.2

**The Sodium Hydride Process and Its Application to the Cleaning of Moulds for the Glass Industry.** N. L. EVANS. *J. Soc. Glass Technol.*, **34**, 55-59 (1950) Apr.

Cleaning and descaling of metal molds by sodium hydrite is said to be speedy and to be free of attack on the base metal. Describes apparatus and procedure.—BLR.

5.9.2

**Metal Cleaner Efficiency (Spotlighting Finishing Progress).** A. G. GRAY. *Products Finishing*, **1950**, 80-88, Nov.

The importance of the physical and chemical nature of a metallic surface which must be cleaned prior to plating or other finishing is stressed, as is the importance of equipment properly engineered and designed to perform the function of removing oils, greases and extraneous materials from metallic surfaces. The relationship between alkaline cleaner formulation and its efficient operation is described and a number of simple practical tests for measuring cleaner efficiency are listed.—TDD.

5.9.2, 6.4.2

**Cleaning and Etching of Aluminium Alloys.** W. R. MEYER. Paper presented at the Electrochemical Society Meeting, Buffalo (U.S.A.) Oct. 11-13, 1950. *Metal Finishing*, **48**, No. 12, 73 (1950) Dec.

In this paper the author discusses the various types of cleaning materials, such as solvents, emulsion cleaners, alkaline cleaners. Under emulsion cleaners he states that the stability of emulsion test is not significant, as actually a quick-breaking emulsion provided better cleaning qualities. He cites graphite as being the most difficult material to remove from metallic surfaces. In etching type cleaners, smut removal is often a problem. The most common etch cleaners use nitric-hydrofluoric acid mixtures. Polyethylene-lined tanks have proven most suitable for containing these mixtures. Frosting type etch cleaners utilize fluoride additions to the caustic base material to give a good white frosty color. Non-etching cleaners for aluminum contain silicates in the caustic base to inhibit excessive attack. As silicate films remaining on the work may be troublesome, only enough silicate is used to inhibit the caustic attack. Acid cleaners for aluminum are compounded mostly from phosphoric acid because of its slow rate of attack on this metal. Surfactants or oil displacing materials may also be added to provide wetting and solvent effects.—ALL.

5.9.2, 1.3, 8.8.3

**Cleaning and Preparation of Metals for Electroplating. I.—Critical Review of the Literature.** HENRY B. LINFORD AND EDWARD B. SAUBESTRE. *Plating*, **37**, No. 12, 1265-1269 (1950); *Ibid*, **38**, 60-65, 158-166 (1951) Jan., Feb.

This review has been compiled as part of the work to be carried out under Research Project No. 12, of the American Electroplaters' Society. The review deals with types of soil, dividing them into organic and inorganic and the use of alkaline cleaners, solvent cleaners, solvent-emulsion cleaners and descalers. Last installment covers standards of cleanliness and methods of evaluating cleanliness. 192 references.

5.9.2

**Molten Caustic Bath Provides Rapid, Efficient Method of Cleaning Steel Parts for Painting.** J. E. FRITTS. *Products Finishing*, **1950**, 10-18, Dec.

In this article the employment of a molten caustic bath contained in an electric salt-bath type furnace to remove drawing compound from sheet steel prior to painting is described. Steel parts can be cleaned by this method in 50 seconds. Other details of the cleaning cycle include a number of rinses and a phosphoric-acid solution which forms a phosphate coating on the steel, which serves as an anticorrosive coating as well as a base for the paint which is subsequently sprayed on the steel and baked. Details of the processing equipment, the time cycle, and accessory facilities are included.—TDD.

5.9.2, 7.6.4

**Boiler Waterside Cleaning.** S. GREENBERG, J. L. SMITH, AND A. HOWARTH. *J. Am. Soc. Naval Engrs.*, **62**, No. 4, 835-843 (1950) Nov.

Calcium sulfate, once the most troublesome scale, is well under control. Knowledge of chemical composition and physical structure of any scale is prerequisite to prescribing an acid treatment with any degree of certainty. Sulfuric acid and hydrochloric acid are the most used scale removal solvents but neither is capable of removing some of the silicate scales found in navy boilers. These scales can be removed by supplementing the acid solvent with ammonium bifluoride. Following a discussion of types of boiler scale a description is given of how to remove boiler scale.—INCO.

5.9.2, 5.4.5

**Surface Protection of Steels and Light Metals Against the Special Fuels "T-Stoff" and "C-Stoff."** WALTER-WERKE. Board of Trade, Tech. Inf. & Docs. Unit, FD. 1007/50, 31 Frames.

The resistance of a variety of metals and synthetic materials (including Buna S, enamels, and lacquers) to the above fuels are reported. Several pickling procedures for steels and aluminum alloys are described.—RPI.

5.9.2

**Fundamentals of Electrocleaning—Spotlighting Finishing Progress.** A. G. GRAY. *Products Finishing*, **1951**, 54-72, Mar.

Basic requirements of a good electrocleaner are outlined and a discussion of the nature of a "clean" surface is included. Considerations regarding the use of anodic cleaners or cathodic cleaners for various metals are presented with a full discussion of the advantages and disadvantages of both methods. The author points out that not only must a cleaner be properly formulated but it must be used in the way in which the manufacturer intended in order to obtain the desired results.—TDD.

5.9.2, 5.8.3

**The Mode of Action of Pickling Inhibitors.** (In German.) F. WILLEMS. *Werkstoffe u. Korrosion*, **1**, 239-244 (1950) June-July.

Describes long-term experiments made to determine the effects of different inhibitors in sulfuric acid solutions. Composition of pickling solutions and type and amount of inhibitor are not revealed. Results are graphed, tabulated and illustrated by micro and macrographs.—BLR.

5.9.2, 3.2.2

**Research Shows How Pickling Causes Brittleness in Stainless Steels.** C. A. ZAPFFE. *Materials & Methods*, **32**, No. 4, 58-62 (1950) Oct.

Fundamental studies on the behavior of gases in steel resulted in a better understanding of the difficulties encountered in pickling and suggested ways of avoiding failures. One of the most surprising discoveries concerned the great sensitivity of the hardenable grades of stainless steel to pickling brittleness, and specifically the fact that commercial inhibitors added to the pickling solution customarily increase the embrittlement beyond that caused by the raw acid. Discussion includes a microscopic view of the embrittlement process, cold work and martensite as factors, other factors, temperature of the bath, a comparison of steels and promoter elements. Diagrams are included.—INCO.

5.9.2

**Pickling and Pickling Acids.** W. SAVELSBERG. *Metalloberflache*, (B), **2**, No. 1, 12 (1950).

For the removal of dirt and slag inclusions from the surface of objects to be brass plated, a pickling solution containing hydrochloric acid and ferric-chloride is superior to the usual sulfuric acid solution.—MA.

5.9.2, 5.4.5

**Modern Techniques in Paint Stripping.** HARRY FORSBERG. *Ind. Finishing*, **25**, No. 5, 36+ (1949).

In stripping of paint and baked finishes from conveyor hooks and workholders and from rejected work requiring refinishing is discussed in detail. Forsberg points out that modern cold-stripping solutions can now remove the coatings in 2 min. Methods of arranging for continuous stripping of the paint from conveyor hooks are described, and lay-outs of equipment for this purpose are suggested.—MA.

5.9.3

**Metal Finishing by Abrasive Tumbling.** H. M. GOLDMAN. Proc. 37th Annual Convention, Am. Electroplaters Soc. June 1950, 223-243. 7000 words.

This general discussion of abrasive

tumbling—its history, applications, equipment and operational details—mentions the use of zinc alloy die cast slugs as abrasive particles. They are suitable for use with steel or iron parts and with brass or bronze castings. The author also considers solutions suitable for wet tumbling operations on zinc alloy die castings.—ZDA.

5.9.3

**Mechanical Finishing of Metals for Decorative Purposes.** J. B. CAMPBELL. *Materials and Methods*, **32**, No. 5, 81-96 (1950) Nov.

The first part of this review describes the mechanical finishing processes, polishing, buffing, tumbling, blasting, etc., and the second deals with their application to particular metals and alloys. There are short notes on the polishing and buffing of rolled zinc and of zinc alloy die castings in their preparation for plating. Wet and dry barrel burnishing are also briefly discussed.—ZDA.

5.9.3

**Surface Preparation Values and Sandblasting Economics.** A. J. LIEBMAN. *Org. Finishing*, 11, 12-18 (1950) Nov.

Discusses various factors involved in determination of the optimum procedure for surface preparation and paint coating of structural steel. Discusses the various methods for surface preparation, their advantages and disadvantages.—BLR.

5.9.3

**Abrasive-Liquid Finishing of the Surfaces of Machine Parts and Tools.** (In Russian.) SH. M. BILIK. *Stanki i Instrument* (Machine Tools and Equipment), **21**, 9-13 (1950) Sept.

Describes in detail use of abrasive-liquid blasting for the above. Different types of equipment are described and illustrated. Of particular interest is the addition of certain chemical agents to the liquid in order to increase the corrosion resistance of treated parts. Data are tabulated and charted.—BLR.

5.9.3, 6.3.11, 6.4.2

**Silver and Aluminium Polishes.** C. T. SNELL. *Chemical Industries*, **66**, No. 5, 701-702+ (1950) May.

The same polishing compounds or similar formulations can be used to polish aluminumware that are used for silver. There are two basic ingredients in silver polish, an abrasive to remove tarnish and a cleaner to remove the loosened tarnish. The most suitable abrasive for silver is diatomaceous earth which has the proper degree of hardness, particle size and particle shape. Formulae for paste and liquid type polishes are given, and preparation of polishing cloths is described. To clean aluminum, soaped pads of steel wool are satisfactory. Formulae for polishing aluminum are given:

(1) Potash soap ..... 10 percent
Diatomaceous earth ..... 50 percent
Water ..... 30 percent
(2) Ammonium stearate ..... 5 percent
Stearic acid ..... 5 percent
Naphtha ..... 40 percent
Air-floated tripoli ..... 50 percent
—ALL.

5.9.3

**Metal Cleaning with Metallic Abrasives.** R. V. RILEY. *Intern. Chem. Eng.*, **31**, No. 1, 15-19 (1950).

The use of metallic shot and metallic grit for cleaning metal prior to painting is described. The manufacture of these abrasives is subject to rigid scientific and technical control, and products are made to suit the particular cleaning process.—RPI.

5.9.4, 6.4.1

**New Process for Protecting Light Alloys.** *Light Metals* (England), **13**, No. 153, 553 (1950) Nov.-Dec.

The Walterisation Co., Waddon Marsh, Surrey, England, exhibited their phosphating and chromating metal-treatment methods at the International Trade Fair, Toronto, Canada. The process for protecting light alloys, known as Walterisation "L" was specifically recommended. It is claimed that this process is cheaper than anodizing.—ALL.

5.9.4, 6.4.4

**Magnesium Alloy Surface Treatment—Importance of Chemical Buffering.** L. F. LEBROCQ AND H. G. COLE. *Metallurgia*, **43**, No. 256, 53-61 (1951) Feb.

Good buffering power is an important practical requirement for chromate treatment baths for the protection of magnesium alloys. Without it, constant additions of acid are necessary to maintain working conditions. The good buffering properties of the hot half-hour chromate bath at pH 6 are described in detail. Good buffering of a cold chromate bath at pH 4 to 5 can be obtained by addition of chrome alum or preferably potash alum; the action of alkali on potash alum is examined in detail in this connection. Some commercial baths are well buffered over the working range and others are not. Extensive use is made of pH curves in this work.—BLR.

5.9.4

**Influence of the Surface Condition in Cold Phosphatising Processes for Iron.** A. FERRI. *Pitture e Vernici*, **6**, No. 6, 223-228 (1950).

The best results are obtained if the superficial iron oxide is completely removed either mechanically or by chemical pickling. The presence of discontinuous scale is very detrimental; that of rust is less so. The cold phosphatizing process is less effective as an anti-corrosive treatment than either hot phosphatization or painting with a red lead primer and definitely needs to be followed by a coat of lacquer or paint. 28 references.—RPI.

5.9.4

**Amorphous Phosphate Coating for Aluminium Alloys.** A. G. GRAY. *Products Finishing*, **14**, No. 4, 60 (1950).

A surface treatment for aluminum prior to painting consists of immersion in, or brush application of, a mixture of chromic, phosphoric and hydrofluoric acids at 100°-130° F, rinsing and drying. The coating is non-porous.—RPI.

5.9.4

**Anodic Treatment of Manufactured Products.** P. SMITH AND P. SHAW. *Light Metals*, **13**, 449-452 (1950) Aug.

Considers effects of chemical composition, state of the metal (sand, gravity or pressure cast, wrought, degree and type of working, etc.) and design upon the quality of the resulting finish.—BLR.

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5.9.4, 3.5.9, 6.3.9

**The Formation of Molybdenum Disilicide Coatings on Molybdenum.** E. A. BEIDLER, C. F. POWELL, I. E. CAMPBELL, AND L. F. YNTEMA. *J. Electrochem. Soc.*, **98**, 21-25 (1951).

Shows that molybdenum can be rendered highly resistant to oxidation by treatment with a hydrogen-silicon tetrachloride atmosphere at 1000°-1800° C which produces a molybdenum disilicide coating. Coatings thus produced have completely protected the base metal for over 4000 hours in air at 1000° C and for over 30 hours at 1700° C. Thicker coatings, within limits, give proportionately longer lives.—BLR.

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